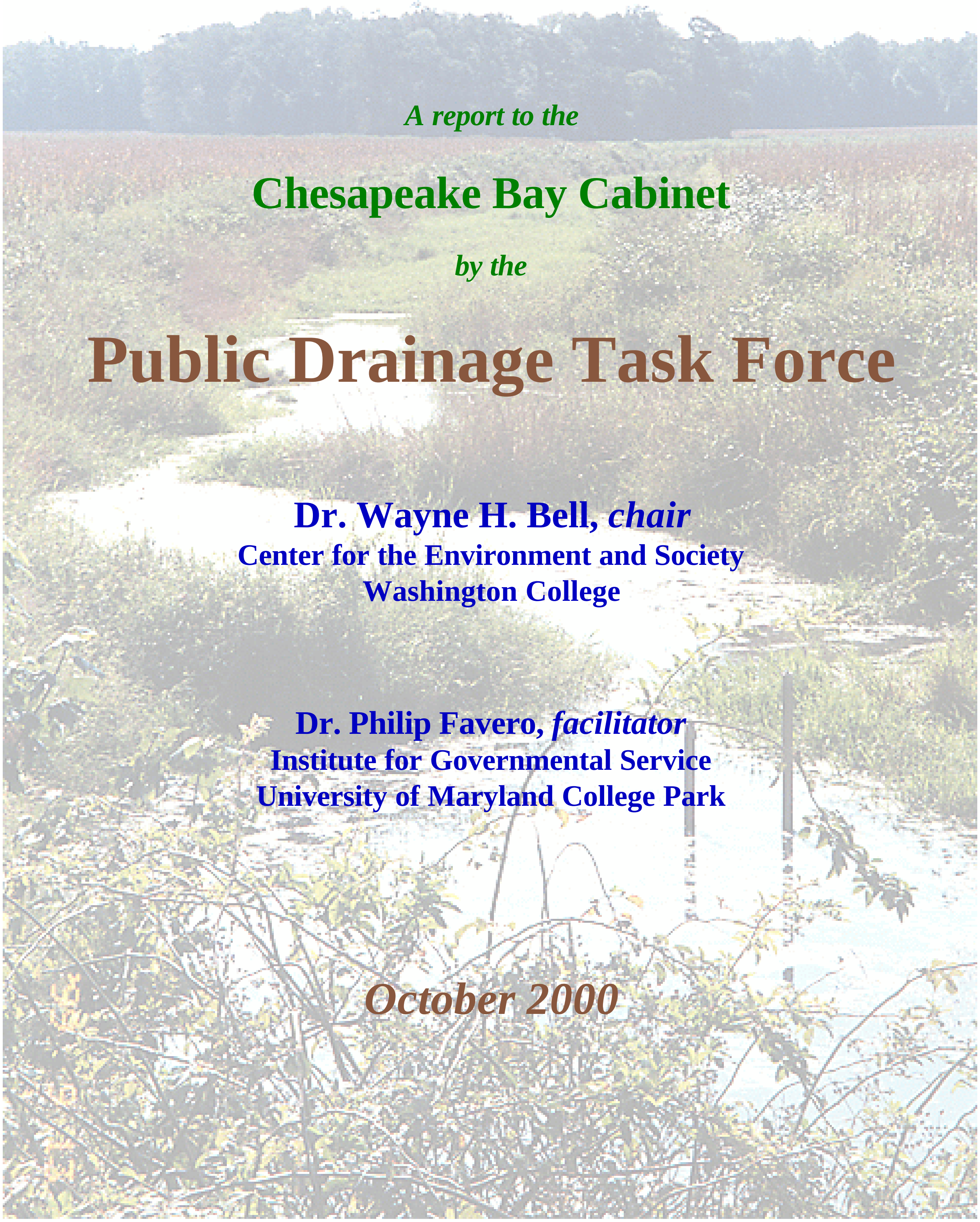
Moving Water



A report to the

Chesapeake Bay Cabinet

by the

Public Drainage Task Force

Dr. Wayne H. Bell, *chair*
Center for the Environment and Society
Washington College

Dr. Philip Favero, *facilitator*
Institute for Governmental Service
University of Maryland College Park

October 2000

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October 2000

Contribution No. 2000 - 1 from the Center for the Environment and Society
Washington College

Unless otherwise indicated, all photographs reproduced in this report were taken by the Task Force chair during tours of Public Drainage Associations and other drainage projects on the Eastern Shore of Maryland and Delaware. The chair is grateful to the following individuals for their patience, concern, and hospitality in arranging and conducting these tours: Michael Sigrist, Richard Parsons, Rai Sharma, Herman Davis, Jim Grindle, David Mister, John Shepard, Eric Buehl, John Bister, and Nick Carter.

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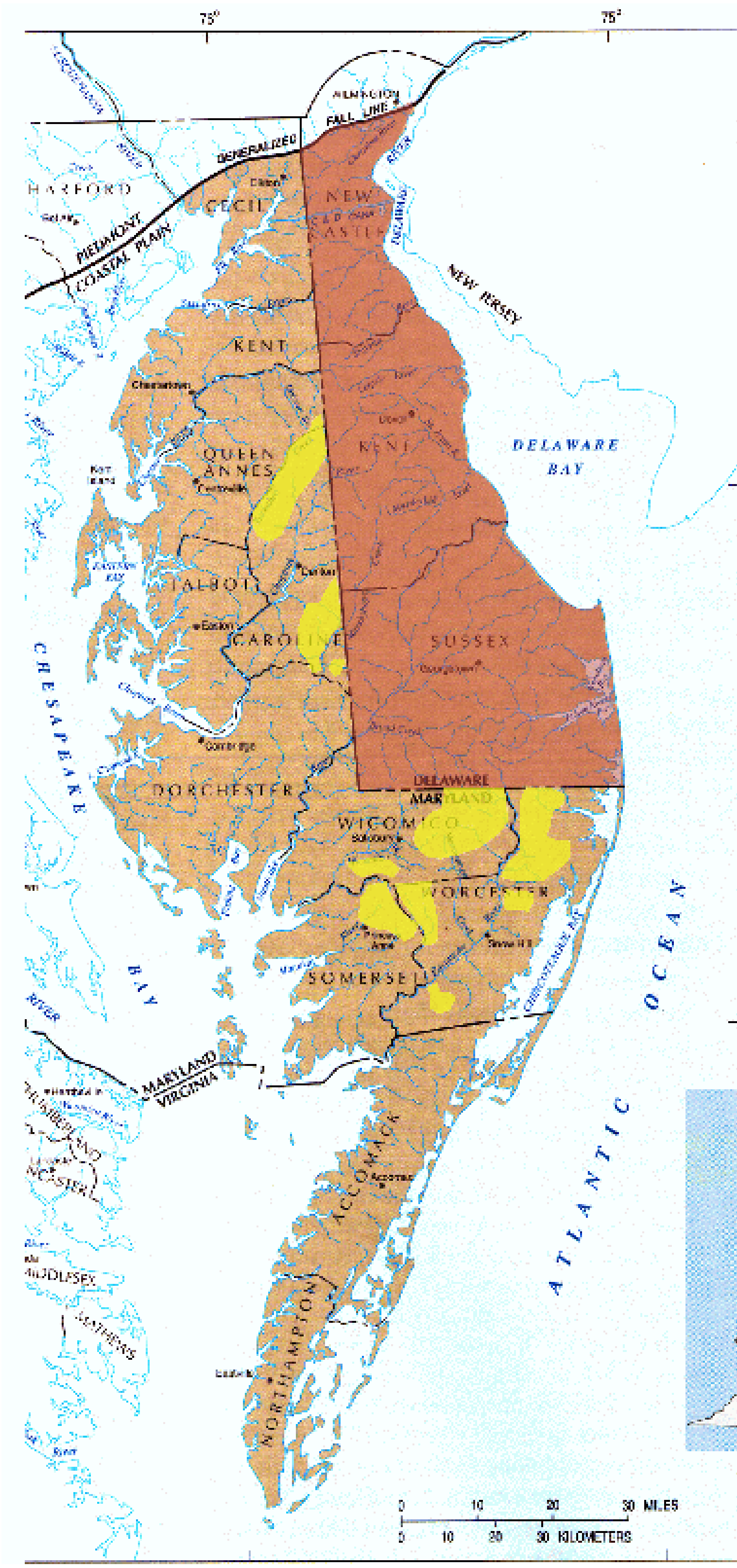
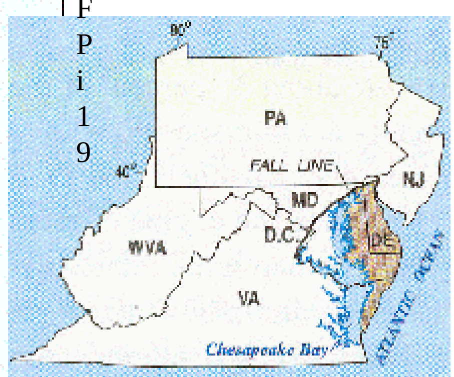
University of Maryland
Center for Environmental Science



Frontispiece. The Delmarva Peninsula. Yellow areas show the general extent of land served by agricultural Public Drainage Associations (PDAs) and Public Watershed Associations (PWAs) in Maryland. Superimposed on these would be a vast network of lines representing roadside ditches, stormwater management conveyances, and drainage on private land. Although public drainage in Delaware was not within the purview of this study, the Task Force is grateful for comment and field trip assistance provided by its representative from that state. [Map modified from Shedlock *et al.*, 1999, with information summarized by Mister (Task F orce P resentat i on, 1 0/20/19 9 9)].



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Executive Summary

In June of 1999, the Public Drainage Task Force was newly constituted and charged by the Chesapeake Bay Cabinet to develop recommendations which would enhance the Eastern Shore environment and the agricultural community by considering changes in public land drainage. The diverse membership of the Task Force was chosen based on interest, background, and expertise that represented the many stakeholders. After just over a year of deliberations, which included numerous presentations by members and invited outside experts, the Public Drainage Task Force has developed the following consensus recommendations:

Recommendation #1.

Policy makers should acknowledge the need to protect the economic well-being of people who depend on effective land drainage while at the same time protecting and enhancing the environment that is affected by public ditches. The objectives to be balanced are efficient drainage of land for farming, forestry, development use, and public transportation, while also as much as possible reducing nutrient and sediment export and enhancing stream and riparian habitat for living resources.

Recommendation #2.

The "on-the-ground" balance of objectives should reflect site-specific conditions as well as overall watershed management goals. Site-specific conditions involve physical, biological, and economic factors. There is need to identify, site-by-site, opportunities for slowing the rate of water flow and improving habitat in and near public drainage ditches without creating uncompensated costs for landowners who depend on public drainage.

Recommendation #3.

Implementation of the recommended objectives should involve the application of best management practices (BMPs) that are based on the most recent results of scientific research. Continual research on drainage design and maintenance methods is essential to further management improvement of public drainage. Therefore, such research and technical assistance to apply research results should receive active support from the State of Maryland. BMPs should incorporate the best achievable methods to reduce nutrient export and increase habitat quality.

Recommendation #4.

Within the next six months the State should create an interagency public drainage coordinating group, to be chaired by a designee of the Secretary of the Department of Agriculture with representatives from Public Drainage Associations (PDAs) and Public Watershed Associations (PWAs) and from each of the Governor's Chesapeake Bay Cabinet agencies. The mission of this group will be to promote and encourage the following:

a) Review existing state guidelines and practices to ensure consistency with recommendations made by the Public Drainage Task Force;
b) Identify needed research, development, demonstration, funding, and technical assistance related to the general implementation of BMPs for public drainage;
c) Establish guidelines which incorporate BMPs for use in the redesign and maintenance of public drainage systems;
d) Cooperate with federal agencies to support State of Maryland objectives; and
e) Coordinate, across State of Maryland and federal agencies, the effective and timely review of permits for drainage redesign and maintenance efforts.

Recommendation #5.

In recognition of the potential public benefits of reliable maintenance efforts that are based on BMPs, State and federal funds should be provided to augment local revenue for maintenance for Public Drainage Association (PDA) and Public Watershed Association (PWA) ditches, to incorporate into their maintenance and redesign efforts progressive outcomes such as reducing nutrient transport, reducing flow, and habitat improvement.

Recommendation #6.

In keeping with the State of Maryland vision for Smart Growth and in compliance with existing laws and regulations, the State should place the burden of costs required for altering public drainage, such as increased costs of maintenance, on to the developers of property to be drained. Alterations would include up-stream and downstream stormwater features (structural and non-structural) to accommodate development, and mitigate expenses.

Recommendation #7.

Watershed management goals must be consistent with the goals of non-point source nutrient load reduction efforts. The State of Maryland should maintain, and, as feasible, enhance and expand current efforts to control nutrient losses from source areas, both public and private lands, before the nutrients reach public drainage ditches.

Members

Wayne H. Bell, chair
Director, Center for the Environment and Society
Washington College

Philip Favero, facilitator
Institute for Government Service
College of Agriculture and Natural Resources
University of Maryland College Park

L. Joseph Bachman
MD-DE-DC District
U.S. Geological Survey

Steven Bieber
Maryland Department of the Environment

Eric Buehl
Sussex Conservation District, Delaware

Nick Carter*
Cooperative Oxford Laboratory
Maryland Department of Natural Resources

Harry Cole
Caroline County Public Works

Robert Davis*
Public Drainage Association Manager
Parsonsburg, Maryland

Lisa Jo Frech
Nanticoke Watershed Alliance

Anne Hairston-Strang
Forests, Wildlife, and Heritage
Maryland Department of Natural Resources

David Harris*
Public Drainage Association Manager
Henderson, Maryland

Donald Jackson
Chesapeake Bay Foundation

James Lewis*
Caroline County Cooperative Extension Service

John McCoy
Maryland Department of Natural Resources

David Mister*
Office of Resource Conservation
Maryland Department of Agriculture

Russell Molnar (alternate Rai Sharma)

Wicomico County Council

Bruce Nichols
Worcester Soil Conservation District, Maryland

Richard Parsons
PDA Coordinator, Worcester, Somerset, Wicomico
Wicomico Soil Conservation District, Maryland

John Shepard
PDA Coordinator. Caroline, Queen Anne's
Caroline Soil Conservation District, Maryland

Michael Sigrist
Natural Resource Conservation Service
U.S. Department of Agriculture

Christopher Spaur
Baltimore District, Planning Division
U.S. Army Corps of Engineers

Sean Smith
Maryland Geological Survey

Helen Spinelli*
Greensboro, Maryland

Kenneth Staver
Wye Research and Education Center
University of Maryland

James Wright
Maryland State Highway Administration

Staff

Christy Mills
Eastern Shore Tributary Team Coordinator

James Newcomb
Dorchester Soil Conservation Office, Maryland

David Nemazie*
Assistant to the President
University of Maryland Center for Environmental Science

* Tributary Team Representative

Introduction and Charge to the Public Drainage Task Force

The Chesapeake Bay Program is a cooperative undertaking by the states of Maryland, Virginia, Pennsylvania, the District of Columbia, the multi-state Chesapeake Bay Commission, and federal agencies led by the U.S. Environmental Protection Agency (USEPA). In 1992 the signatory parties acknowledged that the 40% nutrient reduction goal established in 1987 would not be achieved without addressing nutrient loads from the Bay's 64,000 mi^2 watershed and further amended the Chesapeake Bay Agreement to include reduction and control of point and non-point pollution in the tributaries. The Chesapeake Bay Program was recently extended as *Chesapeake 2000,* a formal recommitment underwritten by extensive public comment and support (Chesapeake Bay Program, 2000).

In accordance with commitments made under the 1992 amendment, the State of Maryland (MD) established a Tributary Strategies program and commenced the gubernatorial appointment of ten Tributary Teams in 1995. The MD Department of Natural Resources (DNR) was given responsibility for coordinating and supporting Tributary Team activities. On 1 July 1998, the Choptank River Tributary Team wrote DNR Secretary John R. Griffin raising a potential conflict between non-point nutrient and sediment control through the use of forested buffers that slow down water movement and the need for adequate land drainage through established public drainage systems (Appendix A). The letter recommended development of best management practices (BMPs) for "channelized streams" through interagency consultation between DNR, Departments of the Environment and Agriculture, the State Highway Administration, and local jurisdictions. After endorsement by the Governor's Chesapeake Bay Cabinet, Secretary Griffin, as Cabinet Chair, convened the "Public Drainage Association" Task Force to meet for the first time on 23 July 1999. Dr. Wayne H. Bell, then Vice President for External Relations at the University of Maryland Center for Environmental Science and now Director, Center for the Environment and Society, Washington College, was appointed Task Force Chair.

Secretary Griffin's charge to the Task Force (Appendix B) went beyond the original focus on BMPs. Membership was expanded to comprise ". . . a broad based group, including representatives of individual PDAs [Public Drainage Associations] and local environmental groups [to] allow a greater exchange of information and ideas, greater buy-in of proposed solutions, and better consideration of issues beyond those associated with PDA operations and maintenance." He further charged the Task Force with ". . . creating a 'win-win' solution for the agricultural community and the environment of our Eastern Shore." As charged, the Task Force initially established its mission and objectives (Appendix C). During these deliberations the members concluded that exclusive concern with PDAs was too restrictive relative to the extent of public land drainage on the Eastern Shore and agreed to change their group's name to the "Public Drainage Task Force" (PD Task Force).

Task Force Activities

In responding to Secretary Griffin's charge, the chair, facilitator, and staff worked together to design and moderate Task Force meetings. Their objectives were to create a process that involved Task Force members in a substantive way, took the time necessary to make well-informed decisions, focused on problems rather than on people and on interests rather than on predetermined positions, and sought to identify options for mutual gain.

The Public Drainage Task Force held eleven meetings, beginning in July of 1999. Each meeting involved a formal agenda, but included also an opportunity for Task Force Members to interact informally over lunch. Prior to the first meeting, the mediator and staff called every Task Force member to ask the following questions:

6. In your opinion, what are the key issues related to public drainage in Maryland?

7. What groups do the issues that you have identified affect?

8. What options are there, in your opinion, for solving the issues that you have identified?

9. What expectations do you have for outcomes of the Task Force?

10. Do you expect there will be shared interests, among Task Force members, that may provide common ground for Task Force outcomes? If so, what are those shared interests?

The staff summarized answers to the questions and reflected them back to members during the first meeting of the Task Force. The summary of answers helped Task Force members understand their differences and their similarities and oriented them toward common interests. During their first meeting, members of the Task Force adopted a mission statement and ground rules.

The Task Force Mission Statement is noteworthy because it spanned the issues surrounding public drainage. It recognized the legitimacy of "protecting the well-being of people who depend on effective public drainage – farmers, residential property owners, highway users, and others," while at the same time "attempting to protect and enhance the environment that is affected by public ditches." As accepted by the members, the mission statement provided a framework for a broad discussion of issues and made the balancing of interests the business of the Task Force. The ground rules included an agreement by Task Force members to "strive for consensus," which the members defined as "being able to live, at least, with what we decide."

After the July 1999 meeting, Task Force work proceeded in three phases. The first phase involved learning about public drainage. Topics for presentations during that phase were as follows:

- History, Management, and Regulation of Public Drainage Associations (David Mister, Maryland Department of Agriculture)

- How Drainage Ditches Function (Dr. Gary Felton, University of Maryland, College Park)

- Drainage Buffers as Nutrient Interceptors (Dr. Kenneth Staver, University of Maryland, Wye Research and Education Center)

- The Economics of Drainage (Presentation by Dr. Douglas Parker, University of Maryland, College Park; Panelists: Sid Richardson - Farmer and PDA Manager; Rai Sharma - Wicomico County; Cal Leuben - Maryland Forestry Association)

- Assessment of Aquatic Resources (Dr. Ronald Klauda, Maryland Department of Natural Resources)

- Water Quality (Dr. Joseph Bachman, U.S. Geological Survey)

- Wetlands (Dr. Kirk Havens, Virginia Institute of Marine Science)

- Hydrology and Geomorphology (Dr. Karen Prestegaard, University of Maryland, College Park)

In anticipation of the first meeting of the learning phase a session was held to plan the presentation by officials from the Maryland Department of Agriculture. All Task Force members were invited to participate in the planning session and several members, with various perspectives on the topic, attended. This method worked well because it involved members directly in designing Task Force meetings and it allowed for diverse views to be considered, informally, before presentations were made to the whole Task Force. Because it was useful, the staff continued the practice of holding planning sessions with a sub-set of members before all Task Force meetings.

The learning phase also benefitted from work done by Sean Smith and Anne Italiano, who developed a “Stream Corridor Management Bibliography” for use by the Task Force.

The second phase of work began in March 2000 and involved creating and selecting options for solving public drainage issues. This phase had Task Force members working in three subgroups – each of which used a set of criteria for selecting options. The topics for discussion in these groups and the criteria for selecting options, posed in the form of questions, were as follows:

A) Public Drainage Design.

What design modifications to public ditches could be used to minimize the adverse effects of drainage systems on the environment and to conserve water resources, while at the same time compensating landowners for the property rights needed to implement the modifications?

B) Drainage Ditch Maintenance

In maintaining public ditches as parts of river systems, what ways are there to minimize the adverse effects of drainage on the environment, while at the same time retaining the efficiency of ditches at acceptable levels?

C) The Relationship between Drainage Ditches and Uplands.

In private land areas that drain into public ditches, what changes in landowner practices are there that would minimize the adverse effects of drainage on the environment, while at the same time preserving landowner rights and compensating landowners for their added expenses?

The final phase of the process involved taking the options developed by the small groups, drafting them into a set of recommendations, and discussing those in Task Force meetings. The objective of this phase was to forge a consensus among Task Force members. After hearing comments by Task Force members, the chairman, with the assistance of the facilitator and staff, wrote a draft report. Task Force members then provided their reactions to the draft and the chairman prepared the final report.

Land Drainage on the Eastern Shore

The total acres involved in land drainage on the Eastern Shore is substantial. In addition to the 821 miles of channelized streams administered by the more than 100 public drainage associations established by law for agricultural

County	PDAs/PWAs	Total Miles	Total Acres
Caroline	68	368	70,137
Somerset	4	42	13,258
Wicomico	13	176	38,903
Worcester	18	235	60,707

Summary of Public Drainage Associations (PDAs) and Public Watershed Associations (PWAs) on the MD Eastern Shore (Mister, Task Force presentation 10/20/99).

purposes[1], there are hundreds of miles of roadside ditches to facilitate transportation. Beyond public land drainage systems is a myriad of farm ditches on private land. Finally, there are new drainage systems built by commercial developers for the purpose of stormwater management. All of these systems functionally interact, overlap, and interdigitate in a bewildering network with one ultimate purpose, *i.e.*, to move water quickly from the land.

History of Land Drainage

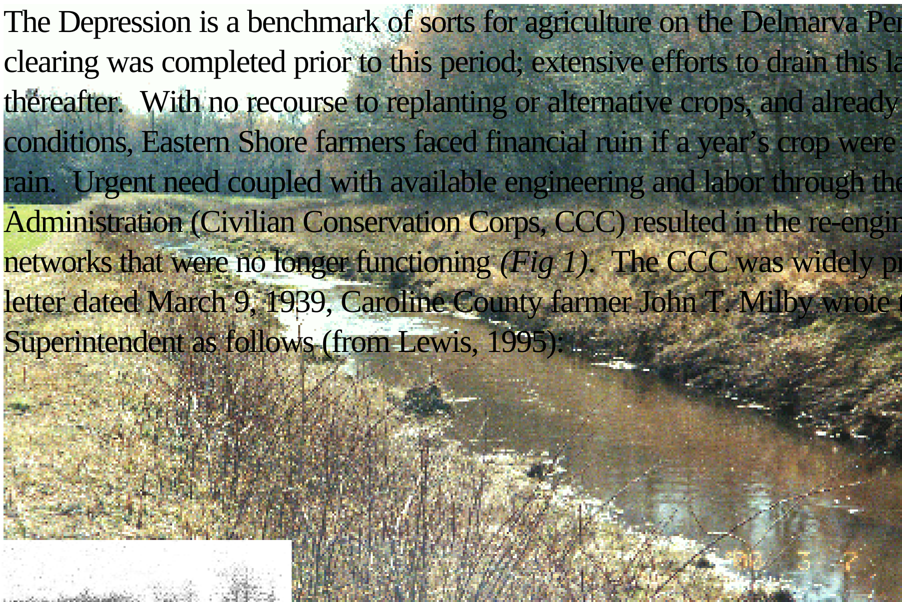
Land drainage has been closely associated with agricultural use of the landscape. The Task Force learned that identifying the land affected by agricultural drainage would highlight most of Delmarva's arable land. Drainage systems for transportation, housing and municipal development, and stormwater management have been connected to or superimposed upon the original agricultural network and purpose on Delmarva. As cropland accounts for approximately 50% of the land use on the Delmarva Peninsula (Shedlock *et al.*, 1999), many of these ditch networks continue to support activities for which they were originally constructed.

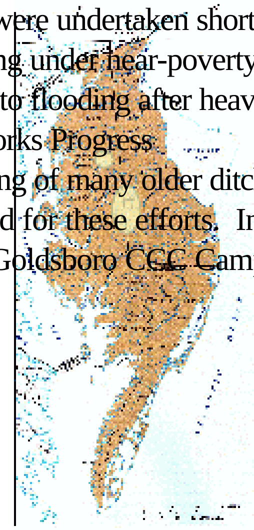
Sustainable, hoe-based agriculture of the region's Native Americans and the early colonists could be carried out on upland soils because organic nutrients (often rotted fish or animal waste) were applied directly to the hills in which crops such as maize, tobacco, beans, and squash were grown. The introduction of European grains and the development of a plow-based agriculture placed a premium on soils that were more productive due to their organic content. These were concentrated in bottom lands and other low relief sites where periodic floods left deposits of rich organic material (Cronon, 1983; Droege, 1996). But despite their inherent richness, in order to grow productive crops on these inherently wet soils, the land needed to be drained.

Organized land drainage began in the U.S. and in Europe in the late 1600's (Iverson *et al.*, 1993; Evans, Gilliam, & Skaggs, 1996). The first recorded project in Maryland was authorized by the legislature in 1789 for the purpose of draining Long Marsh in Queen Anne's and Caroline Counties *(Fig. 1)*. Components of the original endeavor endure today in the Longmarsh Public Drainage Association (PDA) and its sister organizations on the Marshyhope watershed. Pressure to drain the land, primarily on a small scale, continued through the 19th Century. Because slave labor was generally available, the usual practice was to employ hand tools to construct ditches that followed the natural patterns of water flow across the landscape. As local ditching networks expanded and coalesced they created a need for more efficient movement of water downstream. Farmers on the Pocomoke watershed began calling for large-scale drainage projects prior to 1840. In that year the legislature passed the first "Act for clearing out the Pocomoke by means of a lottery" (Anonymous, 1946).

[1]There are an additional 2,000 miles of "tax ditches" in DE, many of which are part of the headwaters of MD land drainage networks (D. Mister, Task Force presentation, 10/20/99)

The Depression is a benchmark of sorts for agriculture on the Delmarva Peninsula. Much of the land clearing was completed prior to this period; extensive efforts to drain this land were undertaken shortly thereafter. With no recourse to replanting or alternative crops, and already living under near-poverty conditions, Eastern Shore farmers faced financial ruin if a year's crop were lost to flooding after heavy rain. Urgent need coupled with available engineering and labor through the Works Progress Administration (Civilian Conservation Corps, CCC) resulted in the re-engineering of many older ditch networks that were no longer functioning *(Fig 1)*. The CCC was widely praised for these efforts. In a letter dated March 9, 1939, Caroline County farmer John T. Milby wrote the Goldsboro CCC Camp Superintendent as follows (from Lewis, 1995):





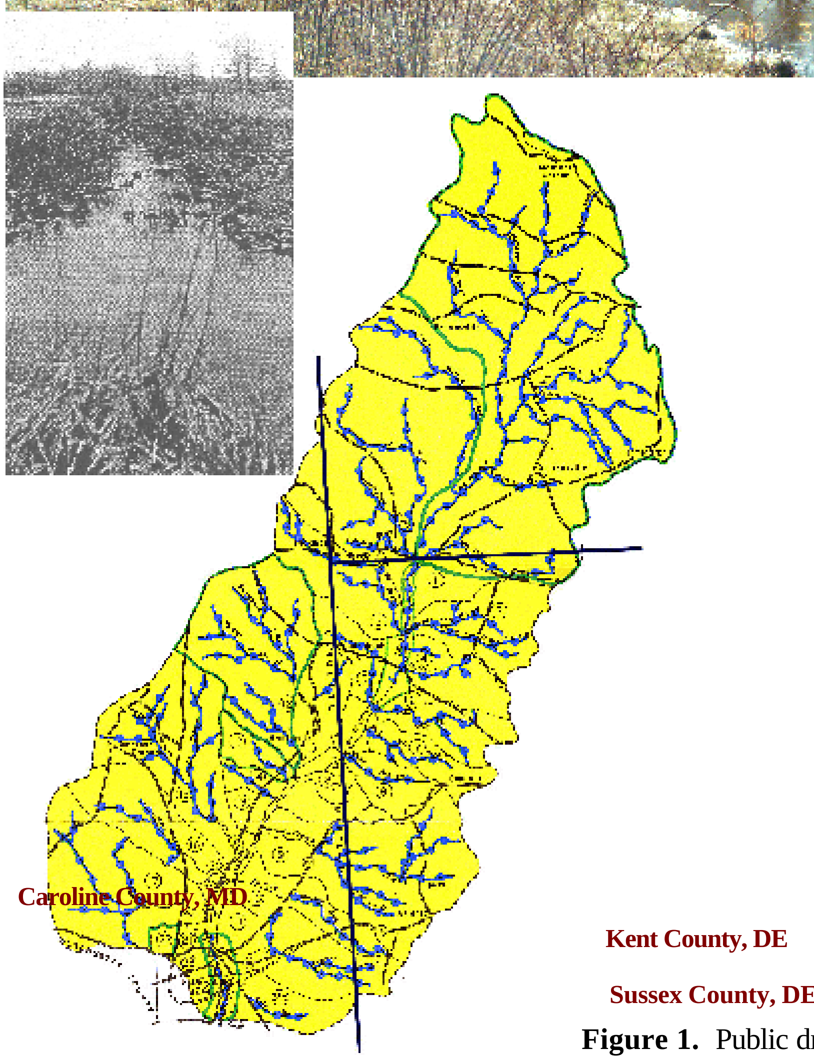


Figure 1. Public drainage in Caroline County, MD, and neighboring Delaware. *Above:* The Long Marsh pro-

ject, (locator map upper circle) authorized in 1789, is the oldest on record. Original ditch was dug by slaves using hand tools. B/W photos show condition of ditch in 1936 *(left)* and after massive reconstruction *(right)* by Civilian Conservation Corps in 1937 (from Lewis, 1995). Color photo shows the main ditch as it exists today as part of the Longmarsh Public Drainage Association. *Lower left:* The Marshyhope Creek Watershed project (locator map lower ellipse), initiated in 1964 and completed in early 1980's. Dotted blue lines show the channelized streams, totaling 260 miles and draining 104,798 acres (from Fincher, 1977).

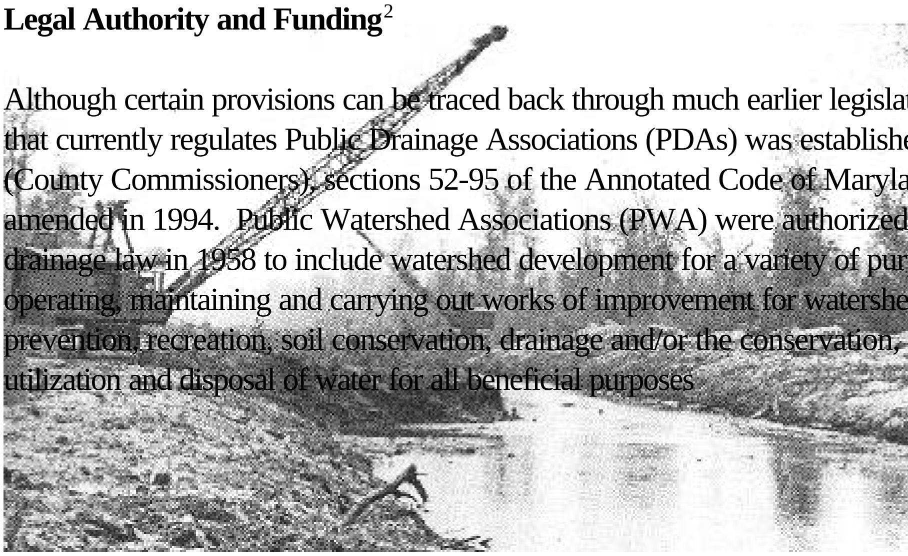
> I wish to commend the work which your camp has done on the digging of Broadway Ditch. I own a farm north of Goldsboro, which this ditch runs thru [sic], and I have been bothered with flooded land after every rain until this ditch was re-dug. Since that time the water runs off rapidly and clears both my land and my tile lines. I have also seen the results of this ditch on farms above me where there were several farms practically water logged which have shown a tremendous improvement in drainage conditions since this ditch was dug. . . .

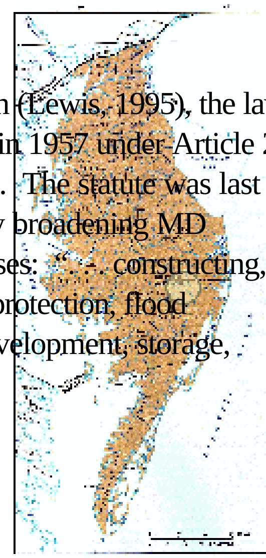
Major new projects were also undertaken with CCC assistance. The Pocomoke project began in earnest in 1940 *(Fig. 2)*. By the time it had reached the Delaware Line in 1946, the original 17-mile river had been straightened to 14 miles, 1,347,474 cubic yards of earth had been excavated, and a right of way cleared through 347 acres of forest. It was the largest project of its kind east of the Mississippi (Anonymous, 1946), eventually resulting in the channelization of 80% of the watershed, the largest so modified in MD (Roth *et al.,* 1999).

The introduction of new techniques and funding subsidies allowed farm ditches to be placed closer together, moving water even more rapidly into the lateral collectors and overwhelming some systems during periods of extended rainfall *(Fig 3)*. Many pre-existing systems were again re-engineered and expanded during the 1960s under Federal Public Law 566 (PL 566; see below). One example, the Marshyhope Creek Watershed Project *(Fig. 1)*, was authorized by Congress in 1964 and completed in about 1983. It included 458 planned miles of channels in existing streambeds, designed to remove excess runoff associated with a 2-year 24-hr storm event. The total project area, 100,600 acres, affected 19% of the Nanticoke River Basin (Fincher, 1977). Another project on the upper Nanticoke brought total channelization of the watershed to 50% (Roth *et al.,* 1999).

Following this second period of new construction, attention in MD has turned to the maintenance of existing drainage systems. The last project, Nebo Road, involving 1.8 miles channelization on 66 acres in Wicomico County, was completed in 1994.

Legal Authority and Funding[2]





Although certain provisions can be traced back through much earlier legislation (Lewis, 1995), the law that currently regulates Public Drainage Associations (PDAs) was established in 1957 under Article 25 (County Commissioners), sections 52-95 of the Annotated Code of Maryland. The statute was last amended in 1994. Public Watershed Associations (PWA) were authorized by broadening MD drainage law in 1958 to include watershed development for a variety of purposes: ". . . constructing, operating, maintaining and carrying out works of improvement for watershed protection, flood prevention, recreation, soil conservation, drainage and/or the conservation, development, storage, utilization and disposal of water for all beneficial purposes

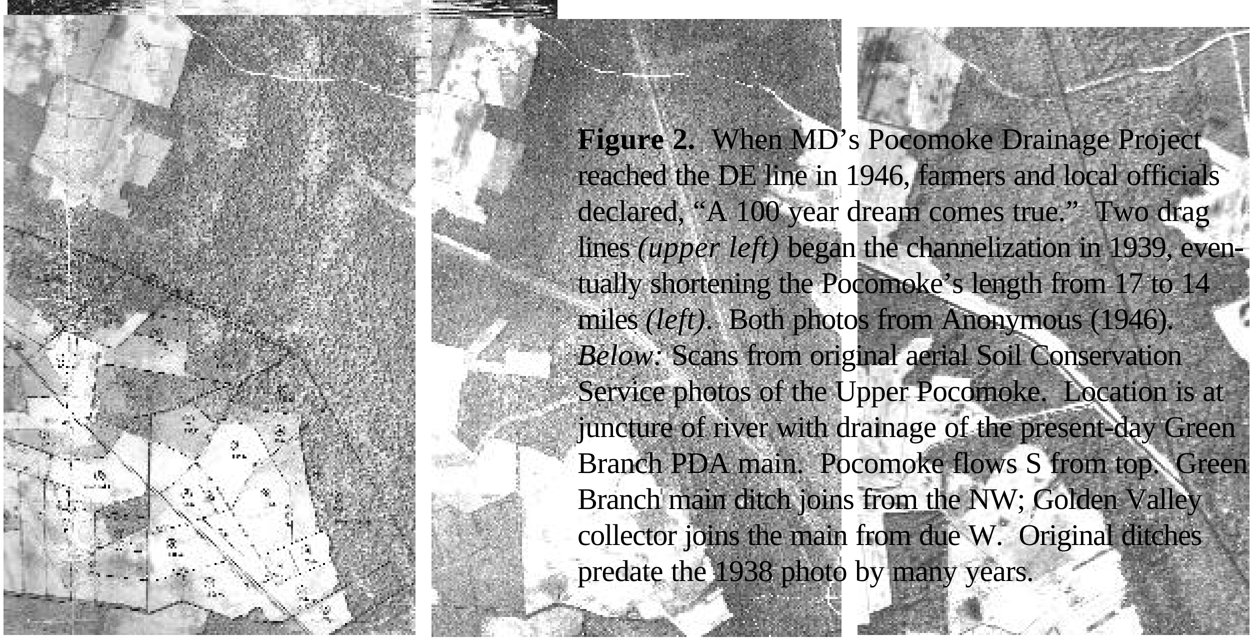


Figure 2. When MD's Pocomoke Drainage Project reached the DE line in 1946, farmers and local officials declared, "A 100 year dream comes true." Two drag lines *(upper left)* began the channelization in 1939, eventually shortening the Pocomoke's length from 17 to 14 miles *(left)*. Both photos from Anonymous (1946). *Below:* Scans from original aerial Soil Conservation Service photos of the Upper Pocomoke. Location is at juncture of river with drainage of the present-day Green Branch PDA main. Pocomoke flows S from top. Green Branch main ditch joins from the NW; Golden Valley collector joins the main from due W. Original ditches predate the 1938 photo by many years.

[2] The Task Force thanks D. Mister and M. Delvecchio for the presentation from which much summary information in this section was derived.

Figure 3. Land drainage and agriculture are intertwined. *Left:* Three scans from the same series of Soil Conservation Service (SCS) photos as in Fig. 2, highlighting a distinctive landscape pattern at a location somewhat West of those scenes. The 1938 scene is pre-Pocomoke Drainage Project. Note the "X" patterns on many fields, the result of machinery turns during hay mowing in these early June photos. By 1952, the SCS was recommending more closely spaced field ditches (drawn in ink on photo) to take advantage of the improved drainage. This was realized before the 1972 photo was taken. In addition, farmers switched from hay to grain crops to support the burgeoning poultry industry. *Above:* At the juncture of the Pocomoke River and Green Branch main ditch. *Top:* The channelized Pocomoke, looking North. *Bottom:* Green Branch main, looking Northwest. See Fig. 2 for location.

1972

in watershed or subwatershed areas . . . ." (Article 25, section 169). As a result of amendments made in 1994, the PDA and PWA laws closely resemble one another. There are 101 active PDAs and 4 active PWAs on the MD Eastern Shore.

Article 25 establishes PDAs as political entities with authority ". . . to locate and establish ditche s, drains, or canals, and to cause to be constructed, straightened, widened or deepened any ditch, drain, or watercourse for the purpose of establishing and maintaining watershed drainage systems . . . ." (Article 25, section 52). They may levy taxes on landowners whose property borders a PDA ditch or is located on a PWA watershed for the purpose of construction and maintenance. Further, they shall ". . . have and possess such rights-of-way and easements as are necessary for the construction and maintenance of the drainage improvements and for the disposition of excavated material . . . ." (Article 25, section 88). PDA/PWAs administer drainage ditches on lands acquired by easement from the original landowners. These ditches function as water conveyance outlets for the farm ditches constructed by landowners on their private holdings.

Watershed protection	Fish and wildlife
Flood prevention	Recreation
Sediment control	Stream flow augmentation
Drainage	Irrigation
Storage of water for water supply	

Types of projects authorized under Federal Public Law 566.

Funding for ditch construction and maintenance was initially provided by taxing the beneficiaries, hence the widespread name "tax ditches." After 1951, some financial support has been provided by local county governments, especially when county road and PDA drainage needs interface. A major resource was created under Public Law 566, the federal Watershed Protection and Flood Prevention Act of 1954. This statute authorized the Soil Conservation Service

(SCS, now the Natural Resource Conservation Service) to assist Soil Conservation Districts in planning and carrying out a wide variety of watershed projects. Through the SCS, the federal government provided approximately 75% cost-share funding for PDA construction; coupled with an additional 12.5% from MD and county funds, extramural support could cover as much as 87.5% of project costs. This resource was largely responsible for a nationwide spate of new projects and CCC project upgrades during the 1950's and 1960's *(Fig. 1)*, underwriting 40 of the 103 currently active PDAs on the Eastern Shore. West Henderson PDA, completed in 1985, was the last to be constructed with Federal Public Law (PL) 566 funds.

PL 566, now called the Small Watershed Program administered by the federal government, still assists local governments in dealing with natural resource and related economic problems on specific watersheds smaller than 250,000 acres in size. But because the U.S. Army Corps of Engineers is no longer issuing permits for new ditch construction, establishment of new PDAs through the Small Watershed Program would now be highly improbable.

Under MD law, only the Maryland Department of Agriculture (MDA) has the authority to provide cost-share funding for maintenance of PDA/PWA drainage (Article 8, Section 602). Cost-share began in 1978 and ended with budget reductions in 1995. It has not been reinstated for routine ditch maintenance, leaving PDA/PWAs dependent on tax assessments and county funds for this activity.

Ditch Maintenance

PDA/PWA easements have a minimum 20-ft. right of way to provide for maintenance of ditch function *(Fig. 4)*. In these systems the process itself begins in the fall or winter with a walking inventory conducted by PDA managers, MDA personnel, landowners, and maintenance contractors. A report describing any problems is prepared with copies to the PDA Chair and MDA; the problems are discussed at the PDA Coordinator's annual meeting with managers. The result is a 1- or 2-year Operation and Maintenance Plan. The Plan is sent to MDA which forwards copies to MDE, DNR, and if operations require permitting, to the U.S. Army Corps of Engineers. After a 60-day comment period the MDA Secretary notifies the PDA Coordinator and managers of plan approval/denial.

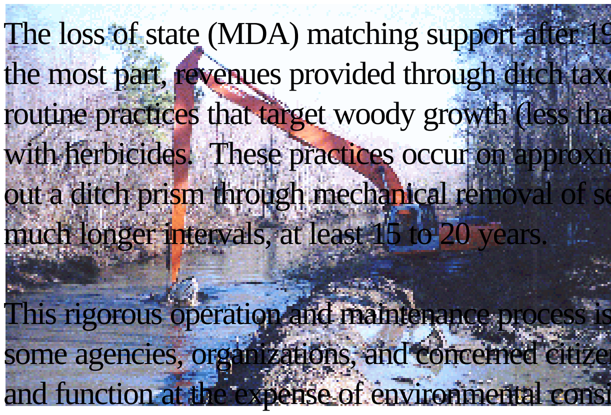
Walking Inventory Items of Concern

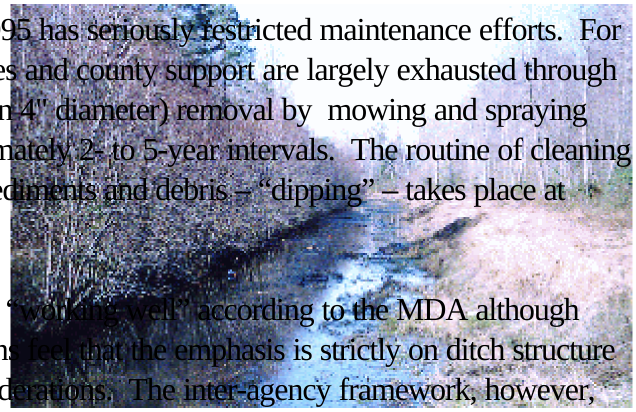
Ditch banks
< areas of failure
< gullies
< areas devoid of vegetative growth

Maintenance right-of-way
< gullies that have cut across right-of-way
< clear access
< access to right-of-way entrance
< presence of woody vegetative growth
< non-maintained areas

Channel bottom
< undesirable growth
< sediment bars that change directional flow of water
< downed trees blocking flow of water
< other blockages

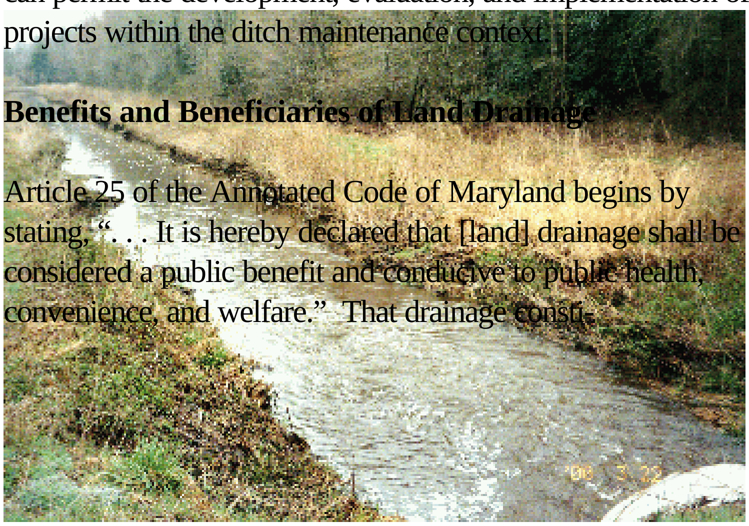
Problems targeted during PDA/PWA walking inventory (Mister, Task Force presentation 10/20/99).





The loss of state (MDA) matching support after 1995 has seriously restricted maintenance efforts. For the most part, revenues provided through ditch taxes and county support are largely exhausted through routine practices that target woody growth (less than 4" diameter) removal by mowing and spraying with herbicides. These practices occur on approximately 2- to 5-year intervals. The routine of cleaning out a ditch prism through mechanical removal of sediments and debris – “dipping” – takes place at much longer intervals, at least 15 to 20 years.

This rigorous operation and maintenance process is “working well” according to the MDA although some agencies, organizations, and concerned citizens feel that the emphasis is strictly on ditch structure and function at the expense of environmental considerations. The inter-agency framework, however, can permit the development, evaluation, and implementation of large-scale, environmentally sensitive projects within the ditch maintenance context.



Benefits and Beneficiaries of Land Drainage

Article 25 of the Annotated Code of Maryland begins by stating, “. . . It is hereby declared that [land] drainage shall be considered a public benefit and conducive to public health, convenience, and welfare.” That drainage consti-

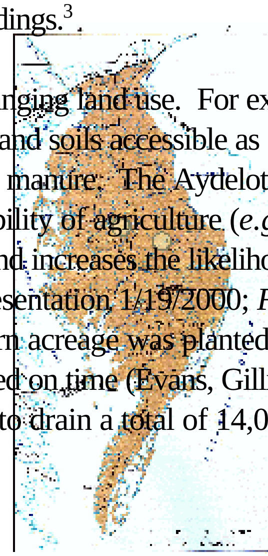
Agriculture Development County and state roads Commercial and municipal organizations Flood control

Benefits of PDA/PWA drainage extend beyond the farming community (Mister, Task Force presentation 10/20/99).

Figure 4. Ditch maintenance. *Upper:* “Dipping” the Gravelly Branch Tax Ditch near Georgetown, DE (right circle on locator map); Dec. 1999. This is the first such sediment removal since the project was completed in 1972. Properly performed dipping is not supposed to damage woody growth on bank *(left)*; view upstream *(right)* looking downstream toward dipout (not in sight) shows original condition of bank. *Left:* Typical result of two-sided, biennial mowing on Smithville PDA *(upper)*, part of Marshyhope Drainage Project in MD (left circle on locator map). Periodic cutting of woody growth under 4" in diameter *(lower)* is a routine maintenance practice for most MD PDA’s and PWA’s.

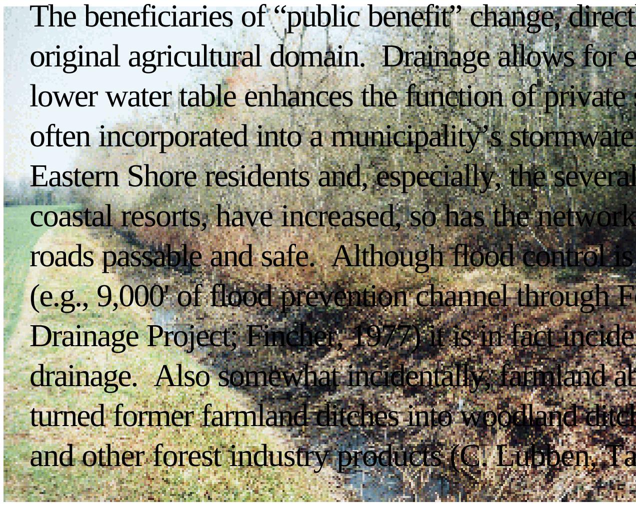
tutes a "public benefit" has been reaffirmed by subsequent legislative findings.[3].

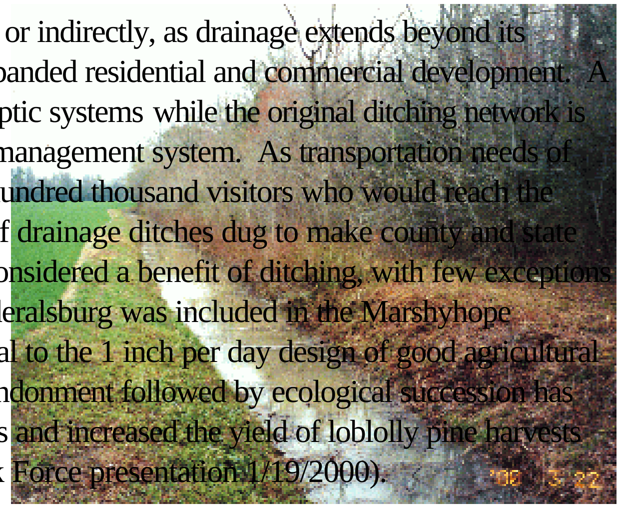
However, the functional benefits of land drainage have evolved with changing land use. For example, the original intention of lowering water table levels to make rich bottomland soils accessible as farmland has been supplanted in this day of chemical fertilizers and excess animal manure. The Aydelotte PDA Manager told the Task Force that drainage today increases the predictability of agriculture (*e.g.*, more timely application of fertilizer and cropping at time of maximum yield) and increases the likelihood that there will in fact be a harvest each year (S. Richardson, Task Force presentation 1/19/2000; *Fig. 5*). In eastern North Carolina, for example, less than 50% of the normal corn acreage was planted during the wet spring of 1989 while virtually all of the drained fields were planted on time (Evans, Gilliam, and Skaggs, 1996). Ditches of the Aydelotte PDA were dug in the 1960's to drain a total of 14,000 acres in eastern Wicomi co County (part of the Pocomoke system).



[3]See, for example, Article 8 (Agriculture), Section 603, (b) Legislative Findings: "[The General Assembly continues to find that the drainage of surface waters from lands for agricultural purposes by public drainage associations represents a public benefit."

The beneficiaries of "public benefit" change, directly or indirectly, as drainage extends beyond its original agricultural domain. Drainage allows for expanded residential and commercial development. A lower water table enhances the function of private septic systems while the original ditching network is often incorporated into a municipality's stormwater management system. As transportation needs of Eastern Shore residents and, especially, the several hundred thousand visitors who would reach the coastal resorts, have increased, so has the network of drainage ditches dug to make county and state roads passable and safe. Although flood control is considered a benefit of ditching, with few exceptions (e.g., 9,000' of flood prevention channel through Federalsburg was included in the Marshyhope Drainage Project; Fincher, 1977) it is in fact incidental to the 1 inch per day design of good agricultural drainage. Also somewhat incidentally, farmland abandonment followed by ecological succession has turned former farmland ditches into woodland ditches and increased the yield of loblolly pine harvests and other forest industry products (C. Lubben, Task Force presentation 1/19/2000).





The evolving uses of land drainage on the Eastern Shore largely have been superimposed on the original agricultural design. This marriage has not always had its benefits, particularly where stormwater management is concerned (Sharm a, Task Force presentation 1/19/2000; Pensyl, Task Force Presentation 4/19/20 00). When developers build private homes as well as fences and outbuildings next to former agricultural ditches, access for maintenance is often lost *(Fig. 5)*. Brush, sediments, and trash accumulate. At best, this creates an eyesore that can reduce the enjoyment and value of property. At worst, stormwater backs up and floods property upstream with similar consequences. Developers do not view the improvement of drainage at downstream locations away from their holdings as their responsibility. Municipalities are forced to perform what maintenance they can where ditches and public roads intersect.

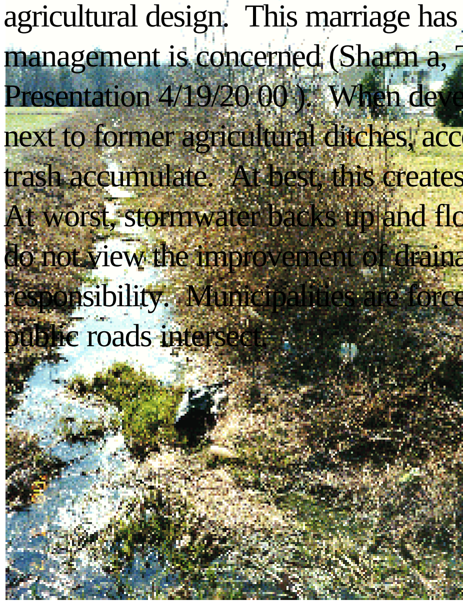


Figure 5. *Upper:* A farm on the Smithville PDA before (13 March, *left*) and after (22 March, *right*) a 24-hr 2-in rainfall event in spring 2000. Neighboring field exhibited no standing water after this event. Another beneficiary, development, can pose serious challenges for maintaining the effectiveness of pre-existing agricultural drainage systems. In Ridgley, MD, private lots abut an agriculture drainage ditch, preventing access for maintenance along the Chicken Bridge PDA easement *(left)*. Some suburban ditches in Salisbury, MD, contain trees several decades old *(lower right)*. As another view in Ridgley shows *(lower left)*, development also adds impervious surfaces (roads, rooftops, and parking lots). The increased runoff encounters ditches full of trash and debris that has already reduced the effectiveness of their drainage function. This is a major problem where development is superimposed on a drainage system originally designed for agriculture.

The economic benefits of land drainage are difficult to assess. Benefits are viewed as considerable by farmers, forest products industries, and residents who view drainage as “the bread and butter of the Eastern Shore” (Sharma, Task Force presentation 1/19/2000). Against these benefits must be weighed costs ranging from taxes levied on the adjacent and/or benefitted properties for maintenance by PDA/PWAs to a share of the multi-million dollar annual expenses being imposed to reduce nutrient and sediment loads into Chesapeake Bay (USEPA 1999). Economist Dr. Douglas Parker (Task Force presentation 1/19/2000) observed that “The economic value of drainage is capitalized into the market price of the affected land itself.” That value accrues to the owner at the time of improvement – drained land brings higher rents and a higher selling price. The next owners pay the higher price for the land,

and inherit the costs of maintenance. Further, the economic value is based primarily on the certainty of expectations about management options and about yields for drained as opposed to undrained land. The inability to maintain adequate drainage for effective stormwater management, for example, results in more frequent flooding that lowers land values. When formerly drained lands are allowed to become wet once again they can lose a portion of their enhanced economic value. If this is done deliberately through, *e.g.,* a wetland creation project, the affected landowners can expect financial compensation.

Finally, it must be remembered that land drainage in support of agriculture is not unique to the Delmarva Peninsula. It is even more extensive in eastern North Carolina (more than 2 million acres affected; Evans *et al.,* 1996) and the Mississippi River basin (more than 70 million acres affected; NOAA, 1999). In helping to make MD farmers competitive with agricultural enterprises in other regions, drainage brings with it similar additions to and deductions from the broader "public benefit" ledger.

The Task Force has concluded that economic arguments do not clearly resolve issues raised by land drainage. However, when coupled with environmental and engineering considerations, economics can provide important additional guidance for evaluating currently available or new project options.

Environmental Considerations for Best Management Practices

Agricultural ditches have been constructed according to the "C-curve" engineering guideline designed to move a maximum of 1.5 inches per day of rainfall off the land. To the extent that land drainage strictly adheres to this guideline, it is viewed as functioning counter to MD's commitment to nutrient and sediment load reductions, wetland protection, and watershed management made under the Chesapeake Bay and Coastal Bays Programs and reaffirmed in *Chesapeake 2000*. Efficient drainage and zero environmental impact are extremes on a continuum *(Fig. 6)*. The Task Force sought testimony by experts in an attempt to find best management practices (BMPs) that would establish points in between.

> **C-Curve Definition**
> Ditches for drainage of field crops are designed to remove runoff water from the drainage area within a 24-hour period following an ordinary rain. Drainage curves were developed for a particular area to determine the flow rate. These curves are based on the climate, soils, topography and agriculture. In the northern region of the U.S. there are four drainage curves (A, B, C, D). The C curve is for basic drainage for grain crops. C curve drainage removes approximately 1.5 inches of rain within a 24-hour period.

The research literature on land drainage is both diverse and sparse, especially with reference to the Delmarva Peninsula. Ditch behavior relative to nutrient and sediment transport is heavily dependent not only on the landscape itself but on the underlying hydrology (*Fig. 7*; Shedlock *et al.,* 1999). As many Delmarva ditches are at least 70 years old and have a history of re-engineering as well as periodic maintenance, each functions at least in part as an unique system. In short, best drainage management is likely to be a site-specific endeavor (Sims *et al.,* 1998; Bachman, Task Force presentation, 2/16/2000) that will rely on technical information at a level of considerable detail. Some generalizations emerged from the expert presentations, however, and they are summarized here as useful guidelines for BMP development.

Increased nutrient loads are not a consequence of land drainage, but are derived from activities on the land that are permitted by drainage.

The perspective that ditches are conduits between land and receiving coastal waters would have no consequence if the land were not enriched with nutrients. In the case of agriculture, there has been a major increase in the use of chemical fertilizers and animal manure on drained landscapes. To the extent that applications exceed crop needs, ditches become a means of conveying the excesses to receiving waters. Even so, internal processing can significantly reduce the amounts of nutrients reaching the receiving waters relative to inputs at the field edge (Evans *et al.*, 1996). In addition to controlling nutrient loads at the source, BMPs need to be implemented that promote "internal processing" as much as possible.

Sediment loads are low and episodic in properly constructed drainage.

Sediment loads increase dramatically during the 10-20 years following ditch construction (Prestegaard, Task Force presentation 2/16/2000). But in established ditches, 90% of the sediment loss is restricted to a few significant rainfall events per year (Staver, Task Force presentation 12/15/1999). While these loads are not inconsequential for receiving waters, most drainage systems are not engineered to accommodate such episodic events on the landscape. BMPs should reduce the vulnerability of ditches to erosion and increase their ability to retain sediments as much as possible within the system following episodic rainfall events.

Surficial (shallow) aquifers beneath agricultural land are enriched in nitrogen relative to background concentrations in deeper aquifers, and this enrichment finds its way into drainage ditches.

Drainage may promote the movement of water and dissolved chemicals into surficial groundwater because it increases percolation through the soil and reduces surface runoff (Felton, Task Force presentation, 10/20/1999). Drainage is also put in place to rapidly remove excess surface

Figure 6. This ditch on private land near Denton, MD, partially reconstructed in Feb. 2000, demonstrates what can happen when rigorous Operation and Maintenance procedures are not part of the process. In this specific case, a 1:1 ditch bank slope *(upper left)* proves inappropriate for the local soil profile. A 2" 24-hr rainfall event in March 2000 was sufficient to cause significant bank erosion *(upper right)*. The increased sediment loads under these conditions *(lower left)* renders bottom habitat unsuitable for indigenous aquatic life. Although there can be undercutting at times of high flow, vegetated banks remaining after a proper dip-out only a few hundred yards downstream on the same system demonstrate one best management practice that can significantly reduce bank erosion problems *(lower right)*. Established Operations and Maintenance procedures provide an important means of benefitting from past experiences and current knowledge for land drainage. These benefits are readily available to the PDAs and PWAs, but land drainage on the Eastern Shore involves a much wider scope of players. Private landowners are especially important. They need to have better access to the most current information and professional assistance if they are to maximize their benefits from land drainage.

Public Drainage Ditch Best Management Practices

Engineering Changes

In-Channel Sediment Traps - Structures that expand dimensional characteristics of a channel, for the purpose of slowing current velocities and providing storage for transported matter including, but not limited to, clay, silt, sand, and detritus.

Stage-Width Channels - Channels that are constructed to stimulate flood plain functions by using a series of widened terraces at various elevations. The terraces provide expanded areas and increased conveyance for selected flood discharges.

Weir Installation - Construction of dams within channels that partially or fully block outlet delivery and force elevated water release. Design may cause out of bank flow for wetland enhancement or retention of water for assimilation and treatment within watershed.

Water Control and Water Diversion Structures - Structures that force or divert water from one area to other areas for use, treatment or safe removal. Weirs, channels, dams, and valves may function in this way individually or in various combinations.

Irrigation Design Modifications - A planned system in which all necessary water control structures are installed for the efficient distribution of water derived from precipitation, reservoirs, wells, groundwater, etc.

Watercourse Habitat Enhancement

Tolerance of Bottom Roughness and Meandering - Maximize levels of bottom roughness and channel meandering while still achieving acceptable drainage efficiency. Increased channel roughness and sinuousity produce lower channel flows and provide variations in flow velocities that promote in-stream habitat diversity.

Strategic Placement of Logs, Rocks, Brush - Specifically designed habitat conditions achieved through installation of logs, rocks, brush, pools, runs, rapids, riffle, and ripple areas, cover, sand bars, organic deposits, and silt or mud zones.

Shaded Riffles and Pools - Vegetation including trees, shrubs, and herbaceous plants along with topographic variations in bank heights may provide shade source, lowering temperatures and favorably altering flora and fauna communities.

Bank and Contiguous Habitat Enhancement

Woody Growth for Bank Stabilization - Trees, shrubs, and some grasses and herbaceous plants are persistent due to hard fibrous structure, i.e. wood. Usually woody growth has more substantial habitat value for cover, and provides niches for greater species diversity.

1-Sided Ditch Maintenance - Allow one side of the channel to go through natural succession processes while performing maintenance practices from the other side. Maintenance practices include mowing, herbicide application, tree cutting, and excavation.

Weed-Wiper Bar Technology - Herbicide application can be directed at specific plant types or communities based upon height or location. Extended bar has wick or other contact applicator.

Forest Buffers - An area of predominantly trees and/or shrubs located to interrupt the movement of water, nutrients, pesticides, and dust and mitigate the effects of odors, noise and undesirable flow water where infiltration rates are slow. In the Chesapeake Bay coastal plain where topography is flat and percolation increased, groundwater contributes 60-70% of the total annual stream(Phillips *et al.,* 1999). Although this groundwater has a residence time of 6-12 years *(Fig. 7),* most drainage projects have been around long enough to have their ditches enriched with nitrogen compounds. Effective BMPs are needed to address both the source of nitrogen and the internal processing necessary to reduce its load to receiving waters.

Excess phosphorus in agricultural soils of the Eastern Shore contributes to elevated phosphorus concentrations in drainage ditches.

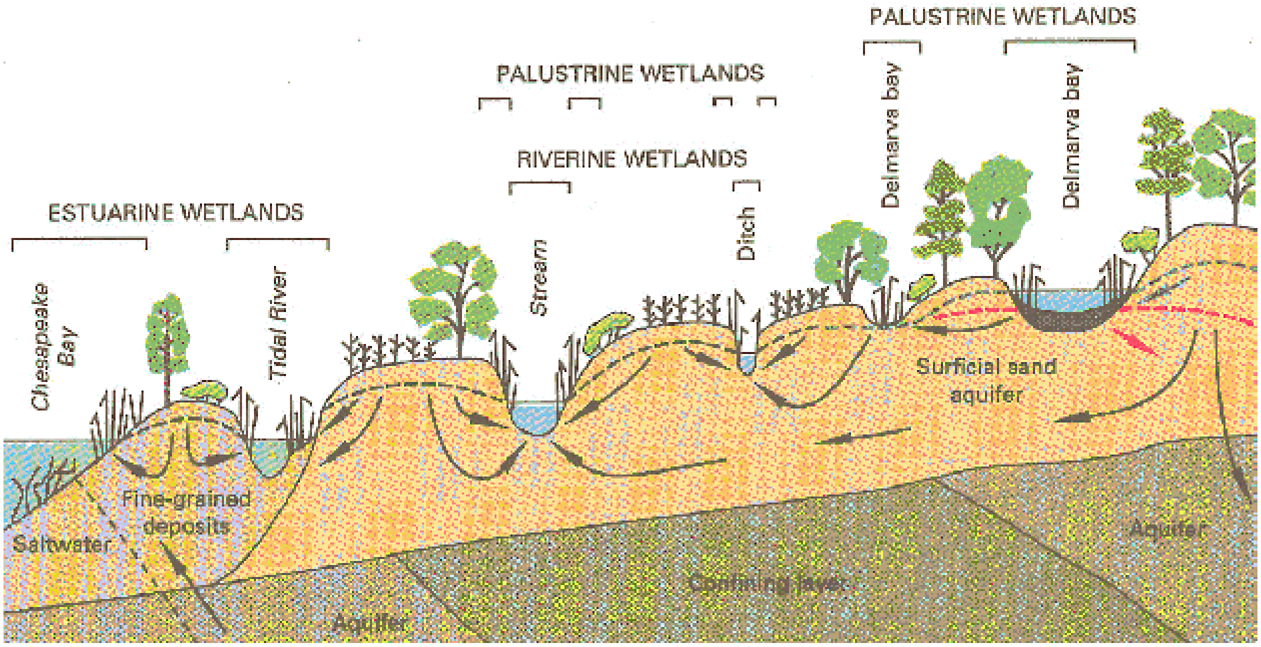
Nutrient	Stream	Shallow aquifer	Ditch
total nitrogen	1.0		
nitrate	0.6	2.0	4. 0 - 5.0
ammonia	0.1		<1.0
total phosphorus	0.1		0 - 1.7
phosphate		0.02	0.01 - 0.05

Background nutrient concentrations in selected aquatic environments (Bachman, Task Force presentation 2/16/2000).

Because phosphorous tends to bind to soil particles under oxidizing conditions, leaching of phosphorous into shallow groundwater is minimal and phosphorous movement from fields occurs predominantly in surface runoff (Staver and Brinsfield, 1994). Repeated fertilization with phosphorous-enriched animal manure has increased soil phosphorous to levels well in excess of those needed for maximum crop production in many regions of the Maryland Coastal Plain. This increases the potential for export of soluable phosphorous into the drainage system. Because it may take decades to eliminate excess soil phosphorus, and because there are additional sources of phosphorus from groundwater sources (Sims *et al.,* 1998), BMPs are needed to promote internal retention of this compound within the drainage network.

There are fundamental differences in nutrient movement between drainage systems that handle surface runoff and those designed to lower the water table.

Systems that have been constructed simply to move water off the land include farm ditches, road ditches, and stormwater management conveyances. They do not interact directly with the underlying surficial aquifer and are instead most strongly influenced by seasonal and episodic rainfall events. Systems engineered to drain the land, such as the Pocomoke drainage network (Prestegaard, Task Force presentation 2/16/2000), actually lower the water table and therefore directly interact with the underlying aquifer. Nutrient loads in these systems are most strongly governed by base flow. They exhibit less seasonal pattern and may be responsible for at much as 50-70% of nutrient loads to receiving waters, especially in winter when soils are recharging and there is less surface runoff (Sims *et al.,* 1998; McCoy *et al.,* 1999; Phillips, Focazio, and Bachman, 1999; Shedlock *et al.,* 1999). This base flow will be extremely difficult to address through BMPs; at best, perhaps a 50% reduction in nutrient loads could be realistically expected (Felton, Task Force presentation 11/27/1999). This still exceeds the 40% load reduction committed under the Chesapeake Bay Program and is sufficient to expect measurable improvement in the quality of receiving waters (Evans, Gilliam, and Skaggs, 1996).



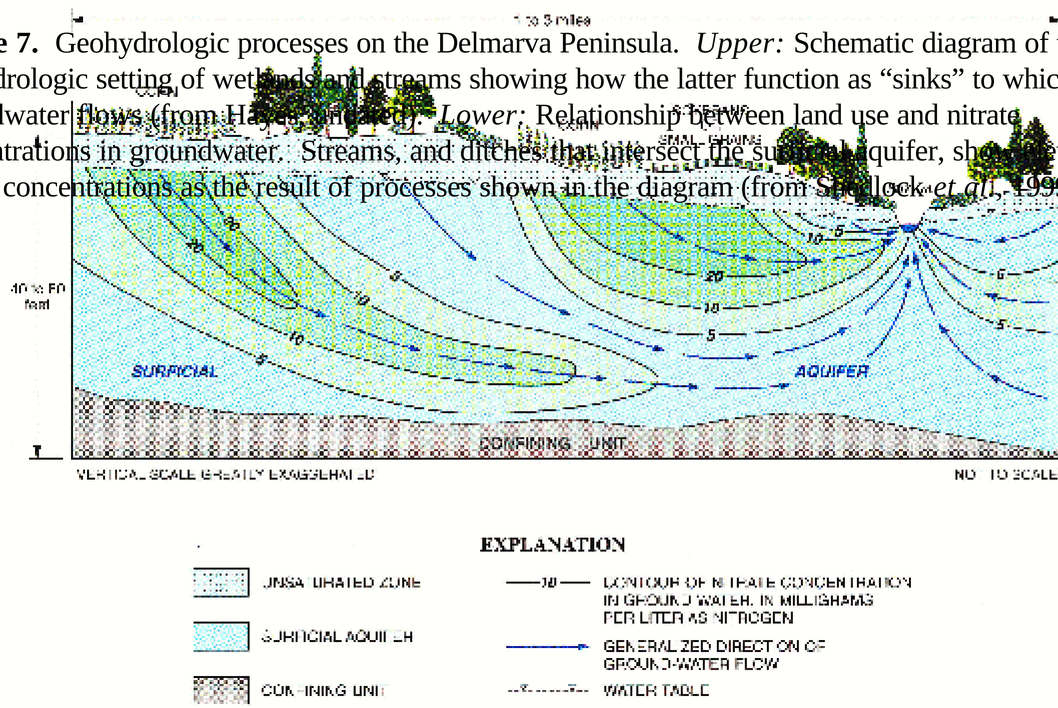


Figure 7. Geohydrologic processes on the Delmarva Peninsula. *Upper:* Schematic diagram of the geohydrologic setting of wetlands and streams showing how the latter function as “sinks” to which groundwater flows (from Hayes, undated). *Lower:* Relationship between land use and nitrate concentrations in groundwater. Streams, and ditches that intersect the surficial aquifer, show elevated nitrate concentrations as the result of processes shown in the diagram (from Shedlock *et al.*, 1999).

Practices designed to slow the transport of water across a drained watershed will allow natural processes to take effect that can reduce nutrient and sediment loadings to the receiving waters.

BMPs that slow the transport of water *(Fig. 8)* can reduce the volume of water discharged as a result of evaporation and uptake and transpiration by plants (evapotranspiration) (Lowrance *et al.*, 1995) . Sediments tend to settle out as water movement slows. During the growing season plants take up and sequester nutrients; rotting vegetation in the sediments consumes dissolved oxygen and creates conditions favorable for nitrogen loss to the atmosphere through denitrification (McCoy *et al.*, 1999). Retention of sediments will also tend to retain particle-bound phosphorus, although phosphorus release is favored in the absence of oxygen (Sims *et al.*, 1998; Bachman, Task Force presentation 2/16/2000). Even the vegetation present in the ditch prism can slow water movement, sequester nutrients, and reduce sediment loss during the warm months (McCoy *et al.*, 1999; Prestegaard, Task Force presentation 2/16/2000).

While adoption of BMPs can reduce nutrient and sediment loads delivered by a land drainage, far greater reductions will be realized by practices that keep nutrients and sediments from entering the ditches in the first place.

Successful implementation of agricultural BMPs and compliance with the MD Water Quality Improvement Act of 1998 can be expected to reduce nutrient and sediment loads that drainage systems can potentially transport to coastal waters. Much more aggressive water table management is also being field tested and adopted *(Fig. 9)*. In eastern North Carolina, for example, there were more than 2,500 water control structures, affecting drainage systems on 150,000 acres, installed by the summer of 1989. The purpose of these carefully monitored systems is both to increase the efficiency of nutrient use by crops and improve drainage water quality (Evans, Gilliam, and Skaggs, 1996).

Exclusive focus on routine maintenance by mowing, spraying, and woody growth removal prevents the recovery of stream habitats on drained lands.

More than 60% of MD headwater streams are impacted by habitat degradation and exhibit concomitant declines in fish community biodiversity (*Roth et al.*, 1999). Stream habitat improvement includes an increased presence of woody debris, bottom structure, and shading (Lowrance *et al.*, 1995). BMPs that include one-sided mowing and an increased tolerance for the presence of woody growth along PDA/PWA easements could be beneficial changes in routine. Such BMPs appear to have a far more immediate effect on stream habitat improvement than attempts to reduce nutrient loads (Primrose *et al.*, 1995).

Figure 8. Examples of best management practices (BMPs). Lack of dipping permits luxurious growth of vegetation in ditch itself, which slows water transport and allows additional time for sedimentation and internal nutrient processing. Example *(upper left)* is the Aydelotte PDA main (locator map left circle). Salisbury, MD, has used public lands *(upper right)* to construct retention ponds that expand to hold more water during heavy rainfall as part of improved stormwater management (locator map middle circle). On Birch Branch PDA *(middle right,* locator map right circle*)* a series of weirs have been constructed to re-establish grade and slow water movement. DE has purchased innovative weed-wiper bar equipment *(lower left, right)* that selectively applies herbicides to control woody plant growth without broadly disturbing other bank-protecting plants. Another BMP practice, 1-sided ditch maintenance, is illustrated in the top photographs of *Fig. 5*.

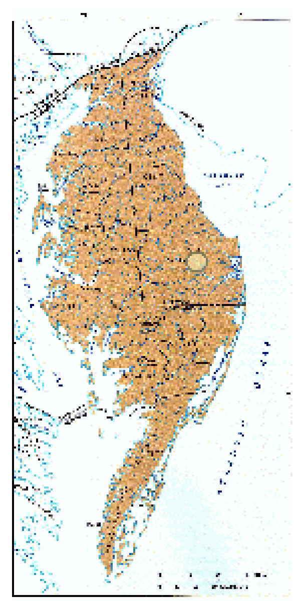


Figure 9. The Sockorockets Tax Ditch, DE, was originally constructed in 1973-1974. The project was re-engineered in 1995-96 as a comprehensive, watershed-oriented endeavor to construct wetlands, restore wildlife habitat, and minimize clearing as part of drainage maintenance. Insertion of boards in water control structures *(top right)* allow water table to be raised during winter, flooding natural wooded non-tidal wetlands *(above left)*. The hydric nature of the resulting soils is shown by the development of cattails, as do the health of sweetgum and red maple trees in the neighboring woods *(lower right)*. The project also employs 1-sided ditch maintenance on the northern side of the easement *(lower left)* that includes tolerance of larger trees; both providing significant shading to the system's outflow waters. This project was not easy to implement; it required extensive landowner negotiations and considerable cost to state agencies. The result, however, has been a net increase of tillable acreage on a landscape that previously had failed to drain adequately for farming.

A watershed perspective is absolutely necessary.

Local "C-curve" drainage need not apply at the scale of the entire watershed. It may be possible to slow transport through parts of the system by diverting water or allowing it to spread out without significantly affecting necessary drainage upstream (Sims *et al.,* 1998). At the present time, limited funding contributes to this lack of perspective and encourages the installation of isolated BMP structures. These may have local significance, but studies on the German Branch watershed indicate they are generally ineffective because their contribution is generally overwhelmed by problems with the larger system (Primrose *et al.,* 1997). BMPs that adopt this perspective can use water control structures not only for water table management but also to divert runoff into existing or restored non-tidal wetlands. The Task Force Chair was shown cogent examples in Maryland and Delaware as to how this potential could be realized *(Figs. 9 and 10)*. All have required substantial infusion of additional funding through the creative use of available state and federal resources and agriculture cost-share programs such as the Conservation Reserve Enhancement Program (CREP) and Environmental Quality Improvement Program (EQIP). The Task Force members agree that a watershed perspective ultimately will resolve the perceived contradiction between land drainage and water quality that presently exists.

Concluding Observations

Drainage has been and continues to be closely associated with land use by human society. On the Delmarva Peninsula, that use has been primarily, but not exclusively, for agriculture. The relationship is such that changes in the extent of drainage can be expected to cause or reflect changes in land use. As an example, Denmark, where approximately half of the country's 39,000 miles have been channelized since at least 1800, has embarked on a massive program of stream restoration. But agriculture now employs less than 5% of the Danish workforce (Iverson et al., 1993). Efforts to preserve farming as a way of life on the Eastern Shore must recognize the significance of land drainage to this endeavor. Outside of the agricultural community, few citizens actually understand the origins, purpose, and significance of land drainage.

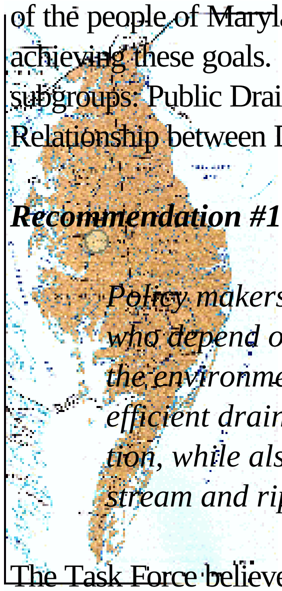
The environmental consequences of drainage, plus the overtaking of agricultural ditches by development and stormwater management, argue that land drainage can no longer be considered the responsibility of a single state agency. PD Task Force members would go further: land drainage is the concern of all who benefit from or who are adversely affected by it. The Task Force itself has provided the first opportunity for representatives from many of these groups to engage in constructive dialogue outside of the regulatory process.

Each member of the Task Force wants to pass to those who would consider its recommendations the importance of recognizing shared goals and respecting individual perspectives. We have learned a great deal about abstract concepts like "consensus," "compromise," and "respect". All of these will be necessary if drainage and society are to coexist with a healthy environment on the Eastern Shore.

Figure 10. A small watershed-based drainage project on the Hubbard-Cohee PDA, MD. CREP funds are used to widen the original 10-ft buffer to 35 ft *(upper left)* with additional erosion protection. EQIP and Clean Water Act Section 319 funds are used to create the heart of the project, a water control structure at an earthen dam across the drainage *(upper right)* that diverts most flow into neighboring wooded wetland (to left in picture, *middle right*). Red maples*(lower right)* bespeak the hydric nature of the soils being maintained by the project. At time of visit (7 March 2000) the ditch below the earthen dam was completely dry despite the presence of running water in the ditch upstream.

Task Force Recommendations

The PD Task Force members are convinced that land drainage must now be approached in a multi-objective context that will meet, as much as is possible, the social, economic, and environmental needs of the people of Maryland. The recommendations that follow have been developed as guidelines for achieving these goals. These recommendations incorporate findings from the three Task Force subgroups: Public Drainage Design ("Design"), Drainage Ditch Maintenance ("Maintenance"), and Relationship between Drainage Ditches and Uplands ("Relationships").



Recommendation #1.

> *Policy makers should acknowledge the need to protect the economic well-being of people who depend on effective land drainage while at the same time protecting and enhancing the environment that is affected by public ditches. The objectives to be balanced are efficient drainage of land for farming, forestry, development use, and public transportation, while also as much as possible reducing nutrient and sediment export and enhancing stream and riparian habitat for living resources.*

The Task Force believes it is possible to maintain functional drainage at the level of the farm field or local development while reducing net nutrient and sediment export through BMPs elsewhere in the same watershed system. This large-scale perspective is as important to each of the following recommendations as it is to Recommendation #1. Without calling for specific changes in the authority or responsibility of the PDAs, MDA, or the NRCS as defined by State and federal law with reference to drainage management and assistance, the Task Force is convinced that a watershed perspective is already altering the way ditching is managed on Maryland's Eastern Shore and that this change will continue with the implementation of its recommendations.

Recommendation #2.

> *The "on-the-ground" balance of objectives should reflect site-specific conditions as well as overall watershed management goals. Site-specific conditions involve physical, biological, and economic factors. There is need to identify, site-by-site, opportunities for slowing the rate of water flow and improving habitat in and near public drainage ditches without creating uncompensated costs for landowners who depend on public drainage.*

Both the "Design" and "Maintenance" subroups have identified actions that could be adopted in a site-specific manner as part of a comprehensive watershed management plan. At the present state of knowledge these actions are not new, but their adoption in this context would be a significant departure from past practice in Maryland. The guiding principle is, where possible, to reduce "C-curve" drainage by retaining water on the landscape for longer periods of time overall. This promotes nutrient transformation and retention through chemical and biological processes, sediment deposition as opposed to transport, and increased water loss to the atmosphere through evapotranspiration. The Task Force is especially interested in the potential of using water control structures, not just for water table management, but also for the diversion of water from ditches into neighboring habitat to create, restore, or expand existing wetlands. This is a form of drainage water remediation that can remove excess P by chemical precipitation, promote denitrification and N uptake by plants, and reduce water volume by transpiration and increased groundwater recharge. Engineering changes such as these can help reduce nutrient loadings from ditched landscapes as called for by commitments made under the Chesapeake Bay and Maryland Coastal Bays Programs. Watercourse and bank and contiguous habitat actions also support the state's Green Infrastructure initiative in which critical habitat hubs are connected by bio-corridors that can be comprised, in part, by ditch rights-of-way. Such watershed-scale endeavors require an inventory of ditching relative to habitat infrastructure, a task best carried out through GIS analysis. In most cases, landowners would have to sacrifice some productive land for the sake of habitat improvement. No such endeavors must be undertaken without appropriate cost-sharing or other form of compensation.

Recommendation #3.

> *Implementation of the recommended objectives should involve the application of best management practices (BMPs) that are based on the most recent results of scientific research. Continual research on drainage design and maintenance methods is essential to further management improvement of public drainage. Therefore, such research and technical assistance to apply research results should receive active support from the State of Maryland. BMPs should incorporate the best achievable methods to reduce nutrient export and increase habitat quality.*

The "Relationships" subgroup specifically identifies the need for more research on nutrient reduction, sediment transport, and aquatic habitat improvement on ditched Delmarva landscapes. Research is necessary both to understand the site-specific behavior of individual ditched watersheds as well as to identify principles that could guide BMP implementation on a majority of systems on the Delmarva Peninsula. The "Maintenance" subgroup notes the importance of adopting BMPs designed to minimize nutrient and sediment transport and calls for field-testing to prove their effectiveness. Studies are also needed on improved ditch design and strategies to prevent stormwater overloading as a result of development. Both groups recommend research leading to the development of indices that incorporate factors such as water quality, animal populations (wildlife, fish, and benthos), economic benefit, and quality of life on ditched land. Indices would then be used as part of long-term monitoring and assessment of discharge into and from public drainage systems. With research generating improved practices, appropriate staff support for the technical agencies will be necessary to educate landowners and local government officials on their implementation. Broader public education efforts are also recommended to inform all landowners about the local and downstream effects of ditch maintenance. Finally, as BMP adoption will incur added costs to landowners and may take agricultural land out of production, research is needed to estimate the funds necessary to underwrite appropriate long-term assistance programs including, but not limited to, cost sharing, tax credits, and tax incentives.

Recommendation #4.

> *Within the next six months the State should create an interagency public drainage coordinating group, to be chaired by a designee of the Secretary of the Department of Agriculture with representatives from Public Drainage Associations (PDAs) and Public Watershed Associations (PWAs) and from each of the Governor's Chesapeake Bay Cabinet agencies. The mission of this group will be to promote and encourage the following:*
>
> *b) Review existing state guidelines and practices to ensure consistency with recommendations made by the Public Drainage Task Force;*
>
> *c) Identify needed research, development, demonstration, funding, and technical assistance related to the general implementation of BMPs for public drainage;*
>
> *d) Establish guidelines which incorporate BMPs for use in the redesign and maintenance of public drainage systems;*
>
> *e) Cooperate with federal agencies to support State of Maryland objectives; and*
>
> *f) Coordinate, across State of Maryland and federal agencies, the effective and timely review of permits for drainage redesign and maintenance efforts.*

Task Force members observe that there is no inherent provision for formal, recurrent dialogue about public drainage among state agencies, landowners, and other affected parties. The current procedure for PDA Operation and Maintenance Plan review involves some agencies only at the stage of final approval. A watershed approach to BMPs requires a dialogue that extends beyond the traditional purview of PDA/PWA and local jurisdictional management and involves all pertinent agencies as collaborative partners. The recommended public drainage interagency coordinating group would provide for such dialogue in matters such as identification of projects where BMP adoption would have maximum potential effectiveness and public benefit, procurement and prioritization of financial assistance for BMP implementation, and technical review of recent research for its potential in advancing existing BMPs for maintenance habitat improvement on ditched land. It will be especially valuable in prioritizing and coordinating large-scale environmental programs on the Delmarva Peninsula, such as those proposed in the recent Feasibility Study conducted by the U.S. Army Corps of Engineers. Existing PDA/PWA administration is to continue unaltered, as is the provision of technical support through the NRCS; the public drainage interagency coordinating group will not require legal oversight to carry out its function in public drainage management. However, by collectively reviewing and establishing consensus-based management objectives and funding priorities, the interagency coordinating group would promote the allocation of funding where it would have the most potential benefit to landowners, the watershed environment, and citizens of the Eastern Shore.

Recommendation #5.

> *In recognition of the potential public benefits of reliable maintenance efforts that are based on BMPs, State and federal funds should be provided to augment local revenue for maintenance for Public Drainage Association (PDA) and Public Watershed Association (PWA) ditches, to incorporate into their maintenance and redesign efforts progressive outcomes such as reducing nutrient transport, reducing flow, and habitat improvement.*

In FY 1999, NPS-319 funds were available for limited ditch operation and maintenance with the understanding that the monies would only be available for BMP implementation. Recommendation #5 fully supports this MDA initiative but goes further by including other potential sources of State and federal funding regardless of agency source. Prioritization of projects, identification of funding sources, and recommendations for implementation will be the responsibility of the interagency public drainage coordinating group (Recommendation #4). Funding can range from matching of revenues raised by PDAs/PWAs and local jurisdictions to complete project support. The “Relationships” Group recommends that a sliding scale be developed that relates the proportion of State support to the scope of citizen benefit anticipated to result from any given project.

Recommendation #6.

> *In keeping with the State of Maryland vision for Smart Growth and in compliance with existing laws and regulations, the State should place the burden of costs required for altering public drainage, such as increased costs of maintenance, on to the developers of property to be drained. Alterations would include up-stream and downstream storm-water features (structural and non-structural) to accommodate development and mitigate expenses.*

Although the implementation of practices in accordance with Maryland's new *Stormwater Manual* will increase local water retention times and promote groundwater recharge as opposed to surface runoff, the fact remains that the cumulative effects of development on a given watershed have the capacity to overload a pre-existing system originally designed for agricultural drainage. The "Design" subgroup strongly recommends that developers be held financially accountable for the implementation of downstream BMPs (*e.g.,* multi-stage channel design modifications) necessary to accommodate any increased stormwater discharge rates. It is most desirable, of course, to ensure that a new development project with plans to discharge into a public drainage system adopt stormwater management that retains the original (pre-development) discharge rates. If either of these requirements cannot be met, the development should not be permitted to go forward. The Task Force recommends that the Governor's Smart Growth subcabinet examine the legal basis of regulating development under these considerations and that, if necessary, legislation be changed or new legislation introduced to provide for the appropriate regulatory authority.

Recommendation #7.

> *Watershed management goals must be consistent with the goals of non-point source nutrient load reduction efforts. The State of Maryland should maintain, and, as feasible, enhance and expand current efforts to control nutrient losses from source areas, both public and private lands, before the nutrients reach public drainage ditches.*

The Task Force recognizes that the prevention of nutrient introduction into public drainage ditches is of critical importance in reducing nutrient loads to Maryland's waters. This problem is being addressed in considerable detail by many other programs, including Total Maximum Daily Loads (TMDLs) under the federal Clean Water Act and the Maryland Water Quality Improvement Act of 1998. While nutrient management on the landscape is not directly related to the mission of the Public Drainage Task Force, the "Relationships" subgroup recognizes the significance of these Recommendations to all such endeavors. To the extent that nutrients do enter ditches by runoff or through interaction with surficial aquifers (Sims *et al.,* 1998), maintenance BMPs may also enhance water quality. Ditch maintenance and redesign BMPs should be taken into account when prioritizing the allocation of funds not normally associated with public drainage programs, including Nutrient Management, Wetland Reserve, Conservation Reserve Enhancement Program (CREP), Environmental Quality Improvement Program (EQIP), and land preservation.

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Appendices

Choptank River
Tributary Strategy Team c/o UMCES
P.O. Box 775
Cambridge, Maryland 21613

Appendix A

1 July 1998

The Honorable John R. Griffin
Secretary
Maryland Department of Natural Resources
Tawes State Office Building
580 Taylor Avenue
Annapolis, Maryland 21401

Dear Secretary Griffin:

I would like to thank you for the opportunity to meet with you and the other members of the Bay Cabinet on 16 April. At that meeting, I brought up a conflict between the use and effectiveness of public drainage systems and the need for more forested buffers. Since the Choptank Tributary Strategy Team has been struggling with this issue for well over a year, we look forward to your help.

The Team recognizes the importance of forested buffers and is pleased that the Chesapeake Bay Program Executive Council has adopted a goal of 2010 miles of new forested buffers by the year 2010. We are even more pleased that the Federal and State governments, along with the Chesapeake Bay Foundation and Ducks Unlimited, have pledged to spend $200 million dollars over the next fifteen years implementing the Conservation Reserve Enhancement Program which will compensate landowners for planting forest and grass buffers and restoring wetlands.

While we understand the importance of healthy buffers in slowing down water, taking up nutrients, and holding sediment, the Team also recognizes the need for proper drainage of our land to ensure that farms and roads remain drained and septic systems work properly. Regardless of how, why, or who helped implement the public drainage systems, the reality is that we now rely on these systems for a variety of purposes. In Caroline County alone hundreds miles of public drainage systems, which could also be considered "blue-line" streams, are presently being maintained to move water from our land to larger sub-tributaries.

We do not simply wish to burden you with this conflict without suggesting a way to resolve it. Therefore, we recommend that your Department consider developing, in consultation with the Departments of Agriculture and Environment, representatives from county roads and health departments, and State Highway Administration, a variety of best management practices (BMP's)

for these channelized streams so that they can continue to maintain proper drainage while providing the maximum environmental benefits. We also ask that you consider regional differences in topography when developing these BMP's.

Thank you for your consideration and please let me know if I, or any other Choptank Team member, may be of assistance to you.

Sincerely,

James Lewis
Chair, Choptank Tributary Strategy Team

cc: Chesapeake Bay Cabinet
Mr. Bill Bostian, Chair, Lower Eastern Shore Tributary Strategy Team
Dr. Ray Forney, Chair, Upper Eastern Shore Tributary Strategy Team

Appendix B

rec 07/09/99

Parris N. Glendening
Governor

Kathleen Kennedy Townsend
Lt. Governor

Maryland Department of Natural Resources
Tawes State Office Building
Annapolis, Maryland 21401

John R. Griffin
Secretary

Stanley K. Arthur
Deputy Secretary

June 29, 1999

Dr. Wayne Bell
UMD/Center for Environmental Science
PO Box 775
Cambridge MD 21613

Dear Dr. Bell: Wayne

As you may be aware, the Choptank Tributary Team has raised several issues related to the management of Public Drainage Associations (PDAs). The Choptank Team recommended that a group representing State and County agencies convene to discuss these issues and develop recommendations for a variety of PDA best management practices that reflect the need to maintain proper drainage while providing the maximum environmental benefit.

The Governor's Bay Cabinet has accepted the Choptank Tributary Team's recommendation for establishing a PDA Task Force, and would now like to move forward and make it a reality. A broad based group, including representatives of individual PDAs and local environmental groups will allow a greater exchange of information and ideas, greater buy-in of proposed solutions, and better consideration of issues beyond those associated with PDA operations and maintenance.

As Chair of the Bay Cabinet, I want to thank you for agreeing to chair the Task Force that will address issues related to the management of PDAs. The first charge of the Task Force will be to develop a mission and objectives, and determine whether other workgroups may be needed. The Task Force will be assisted in its early work through facilitation by Dr. Philip Favero of the University of Maryland Institute for Governmental Services. The date of the first meeting is July 23, 1999. You will be notified by separate letter of the time and location for the first meeting.

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JUL 7 1999

Telephone:_________________
DNR TTY for the Deaf: (410) 260-8835
Toll Free #: 1-877-620-8DNR

Dr. Wayne Bell
Page Two

I hope you will accept the Bay Cabinet's invitation to join the PDA Task Force, and assist us in creating a "win-win" situation for the agricultural community and the environment of our Eastern Shore. This is a very important issue, and your perspective and participation is greatly needed. Thank you in advance for your support. Please feel free to contact Ms. Christy Mills at 410-260-8988 should you have any questions.

Sincerely,

John R. Griffin, Chair
Governor's Bay Cabinet

cc: Donald F. Boesch
Thomas A. Fretz
Donna L. Jacobs
Ronald Kreitner
Jane Nishida
Henry A. Virts

Enclosure

Appendix C

Mission Statement
Public Drainage Task Force

The mission of the Public Drainage Task Force is, in general, to attempt to identify ways and means of protecting the well-being of people who depend on effective public drainage – farmers, residential property owners, highway users, and others – while at the same time attempting to protect and enhance the environment that is affected by public ditches.

Appendix D

The Maryland Public Drain-age Task Force

RIVER CORRI-DOR MANAGEME-NT BIBLI-OGRAP-HY

PUBLIC DRAINAGE TASK FORCE
Final Report

Compiled by
Anne Italiano and Sean Smith
Watershed Restoration Division
Maryland Department of Natural Resources
April 2000

Table of Contents

Introduction

This bibliography has been compiled by the Watershed Restoration Division and Maryland Geological Survey of the Maryland Department of Natural Resources for use by the Maryland Public Drainage Task Force. References on the subjects of agricultural drainage, river engineering and management, riparian corridor management, water quality, plants, and wildlife are included in the compilation. The referenced documents include government guidance documents, scientific papers and reports, and text books. Many of the referenced documents have been annotated to provide a brief summary of the content or findings that might be relevant to the Task Force. Where possible, internet links have been provided with the references. The purpose of this compilation is to provide background information that can help guide the Task Force members, natural resource managers, and the agricultural community to the literature that is available on a broad spectrum of topics related to river corridor management.

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phosphorous content of the water at each of the sampling sites, as well as the effects of an expanded lagoon and a created wetland on water quality. According to the authors, the notoriety of the results of the study have led to increased preservation of natural wetlands in North Carolina.

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VIII NRCS Riparian Buffer Conservation Practice Standards

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IX Riparian Zones

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410 Severn Ave. Suite 109, Annapolis, MD 21403, phone 1-800-968-7229 or on-line at:www.chesapeakebay.net/pubs/155.pdf.

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X River Corridor Restoration and Management

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67. Klein, J. 1998. **Sediment dredging and macrophyte harvest as lake restoration techniques**. Land and Water, Vol. 42, No. 3, pp. 10-12.

68. New York Department of Environmental Conservation. 1986. **Stream corridor management: a basic reference manual**. Division of Water, Bureau of Water Quality, State of New York.

69. Shields, F. D., Jr. and N.M. Aziz. 1992. **Knowledge-based system for environmental design of stream modifications**. Applied Engineering in Agriculture; Vol.8, No.4, pp. 553-562. Summary: Three main types of channel modification alternatives mentioned in this article include bank protection, channel straightening and enlargement, and levee construction. In order to integrate environmental features into channel alteration projects, a user-friendly, knwledge-based systems (KBS) can be applied on a case by case basis. Environmental Design of Waterways(ENDOW) is one such knowledge-based system. ENDOW is a computer model that has been developed and reviewed to aid in the design of streambank protection structures, flood control channels, and streamside levees. It is designed to be a simple, quick method of evaluating environmental goals and engineering and institutional constraints. The user is asked a series of multiple choice, true-false, and numeric input questions, which ENDOW tabulates and as a result recommends an environmental feature. This technology was expensive to develop. A survey was conducted of users of ENDOW to determine their satisfaction with the program.

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remove sediment and nutrients. According to field studies in Dare and Tyrrell Counties, swamp filters remove 80 percent of the sediment and 75 percent of the phosphorous from agricultural drainage waters. Water quality, electrical conductivity, and pH were improved by the swamp filter. The team that conducted this research is developing ways to test the depth, speed, and duration of water flow in the swamp.

XI River Ecology

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XII Vegetation

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observed changes. These changes result in elimination of point bar surfaces, channel aggradation, and increased frequency of downstream flooding. As a result, the distribution of vegetation as it occurs on a naturally meandering stream has been disturbed.

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XIII Water Quality

83. Chambers, J. M., T.J. Wrigley, and A.J. McComb. 1993. **The potential use of wetlands to reduce phosphorus export from agricultural catchments**. Fertilizer Research, Vol.36, pp.157-164. Summary: Natural and artificial wetlands have been shown to remove nutrients from passing water. In the Peel-Harvey catchment in Western Australia, three experiments were carried out to test the ability of wetlands to remove phosphorous from agricultural runoff. The first experiment measured the residence time for the removal of phosphorous from the wetland. The second experiment determined the effect of vegetation type and soil on a wetland's ability to take up nitrogen. The third experiment related flow rates through a wetland to phosphorous concentrations therein. The paper presented the following management options for using wetlands as phosphorous filters: 1) divert runoff through existing wetlands, 2) construct artificial wetlands at the outlet of major drain, 3) construct wetland filters and plant wetland vegetation along agricultural drains, 4) use artificial wetlands to filter point sources. The conclusion of this study call for preservation of existing wetlands and wetland vegetation along waterways. However, the study also found that artificial wetlands are limited in removing phosphorous in Australia

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87. Correll, D.L. 1999. **Vegetated stream riparian zones: their effects on stream nutrients, sediment, and toxic substances**. An annotated and indexed bibliography. Smithsonian Environmental Research Center. Edgewater, MD http://www.serc.si.edu/SERC_web_html/pub_ripzone.html

88. David, M. B., L. E. Gentry, D.A. Koviacic, and K.M. Smith. 1997. **Nitrogen balance in and export from an agricultural watershed.** Journal of Environmental Quality. July/August, pp. 1038-1048. Summary: Studies show that tile drains contain high concentrations of nitrate (NO_3^-) in the water from agricultural land. In Illinois, where a large proportion of agricultural production is dependent upon the effective drainage of the land, tile drainage is common. In an effort to understand the relationship between tile drainage, current agricultural practices, and river nitrate concentrations, a study was performed in the Embarras River watershed (Camargo, Illinois) where tile drainage comprises 75 percent to 80 percent of the total land area and 70 percent of the watershed area is managed by tile drain districts. From 1991 through 1996, researchers measured nitrogen (nitrate, nitrite, and ammonia) and water flow rates in the Embarras River at three sites and four drainage tile outflows. From this data collection, the authors developed a nutrient budget for corn/soybean agricultural fields in the watershed. For maize, the most important sources of nitrogen ranked: 1) fertilizer, 2) soil mineralization, and 3) grain harvest. For soybean, the main source of nitrogen was soil mineralization. The average efficiency of nitrogen uptake for each crop was 48 percent for maize and 112 percent for soybean during the study. Soybean values may be overestimated). The study compares land use to the concentration of nitrogen in the river. By estimating the nitrogen budget of the soil in this agricultural watershed, the researchers found that there was a large amount of inorganic nitrogen in the soil originating from fertilizer application and soil mineralization. Of this inorganic nitrogen, an average of 49 percent nitrate was exported to the Embarras river via tile drains. High flow rates caused large exports of nitrogen in the drainage tiles into the river.

89. Donigian, A. S. and B.R. Bicknell, Jr. 1993. **Regional assessment of nutrient loadings from agriculture and resulting water quality in the Chesapeake Bay area**. Agricultural research to protect water quality: proceedings of the conference February 21-24, 1993 Minneapolis, Minnesota. February 1993, p 483-485. (Extended abstract). Summary: To facilitate the 1987 Chesapeake Bay Agreement of a 40 percent reduction in nutrient loadings in the Bay, the Chesapeake Bay Watershed Model was designed to quantify the needed reductions in nutrient imports to the estuary. The model is intended to allow for evaluation of the impacts of land use changes, alternative nutrient management, and alternative agricultural practices. The model is a combination of the U.S. Environmental Protection Agency Hydrologic Simulation Program-Fortran (HSPF) and AGCHEM, a soil nutrient model. The results of the simulation using the model showed that: 1) total nitrogen and total phosphorous were at expected levels for crop land and non-crop land, 2) conventional tillage was higher than conventional tillage in all nutrients except nitrate, and 3) total nitrogen and total phosphorous rates from highest to lowest were found in manure-fertilized fields, conventional tillage plots, conservation tillage plots, urban land, hay land, pasture, and forest. The Chesapeake Bay Watershed Model is currently being used by the EPA Chesapeake Bay Program Office.

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Environmental Research (TIAER)to address pollution from concentrated animal feed operations. TIAER set up a monitoring network in the Upper North Bosque River Watershed of Erath County and a constituency committee consisting of citizens, livestock producers, university researchers, administrative agency personnel, and chaired by a state senator. Recommendations from the constituency committee were incorporated into Senate Bill 503, passed by the Texas Legislature. The bill includes provisions for government financial assistance, a time frame for voluntary adoption of best management practices, and a low-cost, local system for handling complaints. To prioritize pollution problems and target high priority areas, the Texas governmental agencies utilize a micro-watershed approach.

91. Lichtenberg, E., B.V. Lessley, and H.D. Howar. 1991. **Maryland farmers' adoption of best management practices for nonpoint source pollution control**. Bulletin - Cooperative Extension Service, University of Maryland; Vol. 345. 1990/1991. Summary: The University of Maryland Cooperative Extension Service conducted a survey of 208 farmers in the state to determine their views about best management practices in use on their land. The Cooperative Extension Service describes some current structural and managerial best management practices (BMP), and endorses government cost-sharing in the implementation of best management practices. Two hundred eighty farmers surveyed represented the four agricultural regions of the state: the Piedmont, the Upper Eastern Shore, the Lower Eastern Shore, and Southern Maryland. The data was used to assess demographics, perceptions of water quality, types of best management practices, regional differences in adoption, size and types differences in farms, temporal patterns, perceived effects of best management practices, the significance of cost-sharing, and information sources used. The survey highlighted responses related to water quality problems in Maryland and the link between agriculture and water quality. The survey results allowed for generalizations of Maryland farmer's perceptions about the effectiveness and economic value of best management practices. The authors suggested that negative incentives such as taxes or fines may be more effective in increasing the use of best management practices in the state by independent farmers. Also, they found that there is a need for more education outreach to the farmers about these alternative practices.

92. Lilly, J. P. 1991. **Best management practices for agricultural nutrients**. AG– North Carolina Agricultural Extension Service, North Carolina State University; 439-20. March 1991. Summary: Best management practices are defined by the author as methods to control nutrient loading and subsequent water quality degradation while maintaining crop growth. The best management practices discussed in the publication include soil testing and heeding soil test recommendations, setting realistic yield goals, choosing suitable nitrogen sources, applying nitrogen and phosphorous correctly, timing applications correctly, using manure, controlling erosion, managing water flow, and fencing animals away from waterways. The purpose of the publication is to give a general idea of best management practices that are suitable to land throughout North Carolina. Best management practices should be selected for an individual situation.

93. McCoy, J., N. Primrose, P. Sturm, S. Bowen, and C. Mazzulli. 1999. **Upper Pocomoke:: calibration of the agricultural BMP evaluation 1994-1998.** Chesapeake and Coastal Watershed Service, Maryland Department of Natural Resources.

94. Phillips, C. G. and H.G. Marshall. (no date). **Phytoplankton relationships to water quality in Lake Drummond and two drainage ditches in the Great Swamp, Virginia.** Summary: From December 1988 to November 1989, water quality and phytoplankton species were monitored in Lake Drummond and the Washington and Jericho ditches in Great Swamp, Virginia. The conditions in the ditches were compared to each other and to the Lake. The study found the dominant species of phytoplankton in the Lake to be *Asterionella formosa*. This evidence of increasing cyanobacteria abundance is often an indicator of increased nutrient loading and the lowering of pH. Seasonal changes effected nutrient levels and phytoplankton presence. The findings concluded that Lake Drummond is an early stage eutrophic lake.

95. Primrose, N.L., C.J. Millard, J.L. McCoy, M.G. Dobson, P.E. Sturm, S.E. Bowen, and R.J. Windschitl. 1997. **German Branch targeted watershed project: biotic and water quality monitoring evaluation report (1990-1995).** Chesapeake and Coastal

Watershed Service, Maryland Department of Natural Resources.

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